ANL/ECT-3

APPENDIX B

ANL/ECT-3

APPENDIX B

MASTER

**ENVIRONMENTAL CONTROL IMPLICATIONS
OF GENERATING ELECTRIC POWER FROM COAL**

1977 TECHNOLOGY STATUS REPORT

APPENDIX B

**ASSESSMENT OF STATUS OF TECHNOLOGY
FOR SOLVENT REFINING OF COAL**

PREPARED BY

AIR PRODUCTS AND CHEMICALS, INC.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

**ENVIRONMENTAL CONTROL-
COAL UTILIZATION PROGRAM**

ARGONNE NATIONAL LABORATORY

Prepared for
Division of Environmental Control Technology
Assistant Secretary for Environment
United States Department of Energy

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

The facilities of Argonne National Laboratory are owned by the United States Government. Under the terms of a contract (W-31-109-Eng-38) between the U. S. Department of Energy, Argonne Universities Association and The University of Chicago, the University employs the staff and operates the Laboratory in accordance with policies and programs formulated, approved and reviewed by the Association.

MEMBERS OF ARGONNE UNIVERSITIES ASSOCIATION

The University of Arizona	Kansas State University	The Ohio State University
Carnegie-Mellon University	The University of Kansas	Ohio University
Case Western Reserve University	Loyola University	The Pennsylvania State University
The University of Chicago	Marquette University	Purdue University
University of Cincinnati	Michigan State University	Saint Louis University
Illinois Institute of Technology	The University of Michigan	Southern Illinois University
University of Illinois	University of Minnesota	The University of Texas at Austin
Indiana University	University of Missouri	Washington University
Iowa State University	Northwestern University	Wayne State University
The University of Iowa	University of Notre Dame	The University of Wisconsin

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights. Mention of commercial products, their manufacturers, or their suppliers in this publication does not imply or connote approval or disapproval of the product by Argonne National Laboratory or the U. S. Department of Energy.

Printed in the United States of America
Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161
Price: Printed Copy \$12.00; Microfiche \$3.00

Distribution Categories:
Coal Conversion and Utilization
(UC-90), plus UC-90a, -90b,
-90e, -90i, -90j

ANL/ECT-3, Appendix B

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

ENVIRONMENTAL CONTROL IMPLICATIONS
OF GENERATING ELECTRIC POWER FROM COAL

1977 TECHNOLOGY STATUS REPORT

Appendix B
Assessment of Status of Technology for
Solvent Refining of Coal

Prepared by
Air Products and Chemicals, Inc.
Allentown, Pennsylvania
for
Argonne National Laboratory

December 1977

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *EB*

Work sponsored by
Division of Environmental Control Technology
Assistant Secretary for Environment
United States Department of Energy

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

FOREWORD

"Environmental Control Implications of Generating Electric Power from Coal" is a continuing Argonne National Laboratory program sponsored by the Division of Environmental Control Technology of the U.S. Department of Energy. This 1977 Technology Status Report is the third in a series of reports issued as part of the program and represents efforts of Argonne and several sub-contractors. The primary emphasis is on characterizing and evaluating recent developments in available and near-term control technologies through detailed engineering and cost analyses. The report also includes an assessment of the effect of recent regulatory developments and comparative evaluations of several possible control technology combinations.

The main volume of the report is supplemented by seven appendices consisting of subcontractor reports that deal with particular control technologies. Each appendix is a separate volume, as indicated below, and is designed to be understandable without reference to other portions of the report. The

Appendix, Title	Subcontractor
A* Coal Preparation and Cleaning Assessment Study (Part 1), and Appendix (Part 2)	Bechtel Corp.
B Assessment of Status of Technology for Solvent Refining of Coal	Air Products and Chemicals, Inc.
C Assessment of Low-Btu Gas Combined Cycle Power Generation	Foster Wheeler Energy Corp.
D Assessment of NO _x Control Technology for Coal Fired Utility Boilers	KVB, Inc.
E A Review of Technology for Control of Fly Ash Emissions from Coal in Electric Power Generation	Southern Research Institute
F Flue Gas Desulfurization in the United States - 1977	Tennessee Valley Authority
G State-of-the-Art Review for Simultaneous Removal of Nitrogen Oxides and Sulfur Oxides from Flue Gas	Tennessee Valley Authority

* Appendix A is published as two separately bound volumes. Part 1 is the main text and Part 2 consists primarily of data generated by merging coal washability and reserve data obtained from the U.S. Bureau of Mines.

principal volume of the report and the various appendices are issued independently as they are completed, in order to make the information available in a timely manner. Inquiries regarding the availability of specific volumes should be directed to Technical Information Services, Argonne National Laboratory, Argonne, Illinois 60439.

ACKNOWLEDGEMENTS

This report was prepared by Air Products and Chemicals, Inc. and its subsidiary, Catalytic, Inc. The contract officer was Anand S. Gupta and the investigators were:

Air Products and Chemicals, Inc.

Stanley M. Morris
James J. Weber
Chung L. Yeh

Catalytic, Inc.

Michael N. Caraway
Lalit H. Udani

Project management at Argonne National Laboratory was under the direction of G. Narender Reddy and Kenneth E. Wilzbach.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	1
1 PRESENT STATUS OF TECHNOLOGY FOR SOLVENT REFINING OF COAL . . .	1
1.1 BACKGROUND.	1
1.2 PILOT PLANT DATA EVALUATION	3
1.2.1 Current Pilot Plant Activities	3
1.2.2 Wilsonville Data	7
1.2.3 Fort Lewis Data.	26
2 PROCESS ENGINEERING STUDY	42
2.1 DESIGN BASIS.	42
2.2 PROCESS DESCRIPTION	47
2.2.1 Coal Receiving and Preparation	47
2.2.2 Slurry Preparation, Preheating and Dissolving. . . .	48
2.2.3 Hydrogen Recovery.	49
2.2.4 Precoating and Filtration.	49
2.2.5 Solvent Recovery	50
2.2.6 Product Recovery and Solidification.	52
2.2.7 Hydrogen Manufacture	54
2.2.8 Waste Gas Treatment.	56
2.2.9 Waste Water Treatment.	57
2.3 FLOW DIAGRAMS AND MATERIAL BALANCES	58
2.4 ENERGY BALANCE AND THERMAL EFFICIENCY	71
2.5 RAW MATERIALS REQUIRED AND LIMITATIONS.	74
2.6 PRODUCT CHARACTERISTICS	75
2.6.1 Properties of SRC as a Fuel.	75
2.6.2 SRC Burn Test.	78
2.7 DISCUSSION ON MAJOR EQUIPMENT, SIZE AND DELIVERY.	80
2.7.1 Coal Slurry Feed Pumps	80
2.7.2 Slurry Preheater	81
2.7.3 Dissolver.	82
2.7.4 Filters.	83
2.7.5 Product Solidification Units	84
2.7.6 Mineral Residue Gasifier for H ₂ Manufacture.	84
3 PROCESS ECONOMICS	87
3.1 CAPITAL REQUIREMENTS.	87
3.2 ANNUAL OPERATING COSTS.	96
3.3 COST OF PRODUCT	100
3.4 SENSITIVITY ANALYSIS.	102

TABLE OF CONTENTS (Cont'd)

	<u>Page</u>
4 TECHNICAL FEASIBILITY	106
5 SUMMARY	108
6 APPENDICES.	111
6.1 COAL LIQUEFACTION RESEARCH AND DEVELOPMENT.	112
6.2 COAL LIQUEFACTION PROCESS REVIEWS (GENERAL INTEREST). . .	170
6.3 SOLIDS SEPARATION	203
6.4 CHAR UTILIZATION.	216
6.5 SRC PRODUCT CHARACTERIZATION.	222
6.6 SRC PRODUCT UPGRADING	237
6.7 EQUIPMENT DEVELOPMENT	255
6.8 PROPERTIES OF RAW COAL, INTERMEDIATE PRODUCTS AND PROCESS STREAMS	263
6.9 ENVIRONMENTAL CONCERNS.	268
6.10 COAL PROCESSING ECONOMICS	295
6.11 U. S. ERDA REPORTS.	315
6.12 WILSONVILLE SRC PILOT PLANT REPORTS	323
6.13 REPORTS ON FORT LEWIS PILOT PLANT	332
6.14 BIBLIOGRAPHIES.	340

LIST OF FIGURES

<u>No.</u>	<u>Title</u>	<u>Page</u>
1-1	Fort Lewis Pilot Plant Block Flow Diagram.	4
1-2	Wilsonville SRC Pilot Plant.	5
1-3	Effect of Space Time on Hydrogen Consumption	16
1-4	Effects of Hydrogen Consumption.	18
1-5	Specific Resistance vs Filtration Pressure Drop.	25
1-6	Effect of Dissolver Outlet Temperature and Total Hourly Space Rate on Yields and Hydrogen Consumption.	35
2-1	SRC-1 Process FS-1, Coal Receiving and Pulverizing	59
2-2	SRC-1 Process FS-2, Slurry Prep, Preheating and Dissolving . .	60
2-3	SRC-1 Process FS-3, H ₂ Recovery.	61
2-4	SRC-1 Process FS-4, Precoat and Filtration	62
2-5	SRC-1 Process FS-5, Solvent Recovery	63
2-6	SRC-1 Process FS-6, Product Recovery and Solidification. . . .	64
2-7	SRC-1 Process FS-7, H ₂ - Manufacture	65
2-8	SRC-1 Process FS-8, Waste Gas Treatment.	66
2-9	SRC-1 Process FS-9, Wastewater Treatment	67
2-10	Overall Flow Diagram FS-10, 20,000 TPD Coal (KY. 9 & 14) Feed SRC-1 Process.	69
2-11	Overall Energy Balance, Principal Raw Materials and Products, 20,000 TPD Coal Feed SRC Plant	73

LIST OF TABLES

<u>No.</u>	<u>Title</u>	<u>Page</u>
1-1	Typical Analyses of Ground Coals Used at Wilsonville	9
1-2	Typical Operating Conditions with Various Coals at Wilsonville Pilot Plant	10
1-3	Analyses of SRC Produced from Various Coals at Wilsonville . .	13
1-4	Funda Filter Operating Conditions and Downtime (KY #9 & 14 Coal)	24
1-5	Typical Analysis of Ground Coal Used at Fort Lewis	27
1-6	Operating Conditions at Fort Lewis Pilot Plant for SRC-1 Mode of Operation	28
1-7	Typical Analysis of SRC Produced at Fort Lewis	29
1-8	Multiple Linear Regression Models for SRC-I	31
1-9	SRC-I Dependent Variables Used in Regression Analysis	33
1-10	Model Predictions vs. Actual Measured Component Yields	34
1-11	Filtration Test Runs (KY #9 & 14 Coal)	37
1-12	Proposed Optimum Filtration Run	40
2-1	Design Basis for a 20,000 TPD Coal Feed SRC-I Plant	43
2-2	Material Balance - Waste Water Treatment FS-9	68
2-3	Overall Material Balance	70
2-4	Energy Balance and Thermal Efficiency	72
2-5	Properties of SRC as a Boiler Fuel	76
3-1	Comparative Economics, U.S.B.M./Parsons/Southern Company/Gulf Mineral, Capital Costs - Mid-1976, 20,000 TPD	88
3-2	Probable Cause of Cost Discrepancies, Capital Costs	91
3-3	Calculation of Total Capital Requirement Using Skamser Method	95
3-4	Annual Operating Costs - Mid-1976	97
3-5	Pollution Control Costs Within Comparative Economic Models - Mid-1976	99
3-6	Cost of Main Product for 20,000 TPD SRC Plant Producing Solid Product - Mid-1976	101
3-7	Sensitivity Analysis - Prototype Model	103
3-8	Capital Costs for U.S.B.M./Parsons/Southern Company/Gulf Minerals Models as They Appear in Source Documents	104

ENVIRONMENTAL CONTROL IMPLICATIONS
OF GENERATING ELECTRIC POWER FROM COAL

1977 TECHNOLOGY STATUS REPORT

*Appendix B: Assessment of Status of Technology
for Solvent Refining of Coal*

Prepared by
Air Products and Chemicals, Inc.

ABSTRACT

This report reviews the technology and environmental impacts of the solvent refined coal process to produce clean solid fuel (SRC-I). Information on SRC-I pilot plant operation, process design, and economics is presented. A bibliography of current available literature in this technology area, divided into fourteen categories with abstracts of the references, is appended.

The history, current operations, and future plans for the SRC pilot plants at Fort Lewis and Wilsonville are reviewed. Process data generated at these pilot plants for various coals are used as a basis for a conceptual commercial plant design with a capacity to process 20,000 tons per day (TPD) of prepared coal. Block flow diagrams, material balances, an energy balance, and a list of raw materials for the plant are also provided.

Capital cost estimates for a 20,000 TPD coal feed plant derived from four prior economic studies range from \$706 to \$1093 million in 1976 dollars. The annual net operating cost is estimated at \$238.6 million (1976 dollars) and the average product cost at \$2.71/MM Btu based on utility financing (equity 25: debt 75) with \$25/ton as the delivered price of the dry coal.

The report also discusses special technical considerations associated with some of the process operations and major equipment items and enumerates technical risks associated with the commercialization of the SRC-I process.

1. PRESENT STATUS OF TECHNOLOGY FOR
SOLVENT REFINING OF COAL

1.1 BACKGROUND

Solvent refining of coal to produce a clean solid fuel (SRC-I) is a promising technology in the spectrum of environmental control strategies for increasing the use of coal in power generation and in industry. This report represents an initial effort under the Argonne Environmental Control-

Coal Utilization Program to evaluate the technology and the environmental control implications of SRC production and use. It includes:

- An extensive literature search on the SRC-I process.
- Information on various operating SRC pilot plants, their current status and future plans.
- Material balances and block flow diagrams for a 20,000 TPD prepared coal feed plant.
- Energy balance and thermal efficiency estimates.
- Raw materials requirements.
- Product characteristics.
- Capital, operating, and product costs.
- An evaluation of the prospects for commercialization.

The rapid rate of developments in coal processing technology makes it imperative to have early access to the most recent results and conclusions. In order to accomplish this objective, information and data on the technical, economic, and environmental aspects of the SRC-I process were collected for the period spanning the early 1960's to 1977. The appendices to this report present a summary list of references to published information listed in NTIS, ERDA (DOE), and COMPENDEX data banks. An abstract of each paper is included wherever possible. In order to increase the effectiveness of the references, they have been subdivided into fourteen categories of likely interest. These are:

- Appendix 1. Coal Liquefaction (Research and Development)
- Appendix 2. Coal Liquefaction Process Reviews (General Interest)
- Appendix 3. Solids Separation
- Appendix 4. Char Utilization
- Appendix 5. SRC Product Characterization
- Appendix 6. SRC Product Upgrading
- Appendix 7. Properties of Raw Coal, Intermediate Products and Process Steams
- Appendix 8. Equipment Development
- Appendix 9. Environmental Concerns
- Appendix 10. Coal Processing Economics
- Appendix 11. ERDA Reports
- Appendix 12. Wilsonville Reports

Appendix 13. Fort Lewis Reports

Appendix 14. Bibliographies

Within each category the list of references is arranged chronologically by publication dates. Each reference is identified by a three-part numerical code consisting of the section number (6), the appendix number, and its position in the numerical order.

1.2 PILOT PLANT DATA EVALUATION

1.2.1 Current Pilot Plant Activities *(6.12.5, 6.12.6, 6.12.8, 6.12.12, 6.13.4, 6.13.13)

The Solvent Refined Coal process is based on coal hydrogenation processes developed in Germany prior to 1945. Bench-scale work on the process was carried out initially by Spencer Chemical Company and later by Pittsburg and Midway Coal Mining Company (P & M) under the sponsorship of the Office of Coal Research of the U.S. Department of Interior. In 1967, P & M contracted with the Stearns-Roger Corporation to design a 50-ton per day SRC pilot plant. This design was the basis of the 50 ton per day SRC plant at Fort Lewis engineered and installed by the Rust Engineering Company and operated by P & M under the sponsorship of the Office of Coal Research. A block flow diagram of the plant is given in Fig. 1-1. P & M is also carrying out several research and development programs on the SRC process in support of the Fort Lewis operation.

In 1972, Southern Company Services, Inc. and Edison Electric Institute jointly agreed to support a 6-ton per day Industry Test Unit (ITU) to study the SRC process. Catalytic, Inc. was selected to engineer, construct and operate the ITU. The Stearns-Roger design was used as a reference design. It was decided that the ITU would be as small and simple in design as was consistent with obtaining the required information. Therefore, some standard operations, such as coal preparation, hydrogen generation and sulfur recovery process, were not included. Coal preparation is done by an outside contractor and hydrogen is supplied in tube trailers. Hydrogen sulfide is removed by scrubbing with a dilute caustic solution. A flow diagram of the Wilsonville SRC pilot plant is given in Figure 1-2.

* Numbers in parenthesis are number codes for references listed in Volume II.

FIGURE 1-1
FORT LEWIS PILOT PLANT BLOCK FLOW DIAGRAM

FIGURE 1-2

WILSONVILLE SRC PILOT PLANT

After commissioning in October 1974, the Fort Lewis SRC pilot plant was first operated in the SRC-I mode to attain reliable material balance data. The filter was by-passed due to mechanical problems. After necessary modifications, the plant was then run in SRC-II (Slurry Recycle) mode and material balance data obtained.

From September 1975 to the end of November 1976, a production run of solid SRC to produce 3000 tons for a large scale burn test was made. During December 1976 and January 1977 the effect of several variables on filter performance were studied. From February 1977 to April 1977, extensive modifications were made to study a wide range of conditions in the SRC-II mode.

Since the start of this plant, major progress has been made in the development of the SRC process at the pilot plant level. The advances made can be directly utilized in the design of future, larger plants for the commercialization of both SRC-I and SRC-II processes.

The Wilsonville SRC pilot plant began operation with coal in January 1974. During 1974 the plant was operated with Kentucky #9 & 14 and Illinois 6 coals. The first SRC product to meet specifications of 0.96% maximum sulfur and 0.16% maximum ash was produced in June 1974. The overall reliability of the pilot plant was demonstrated in sustained periods of operation of 45 and 75 days. However, mechanical problems with filter, slurry pumps for coal and precoat, letdown valves and filter cake drier persisted; nevertheless, the operation was carried out over a range of operating conditions. It was observed that residence time and dissolver temperature and pressure were the most significant variables.

During 1975 runs were made with two bituminous coals -- Pittsburgh #8, and Illinois #6 (Monterey No. 1 Mine). Also, a sub-bituminous coal, Wyoming Belle Ayr Mine coal of Amax Coal Company was run for the first time. Letdown valves and filter operation improved. Hydroclone units were installed and tested. A light organic distillation column was added. Instead of using the troublesome ash drier, the filter cake was being dried on the filter. A Rexnord product solidifier was installed.

Operation in 1976 was aimed at correlating the results of the Wilsonville and Fort Lewis pilot plant operations due to U.S. ERDA participation in the program. Runs were made with Illinois #6 (Monterey) and Amax, as well as Kentucky #9 & 14, coals. Solvents of different boiling ranges were tested. A solid bowl and a disc and nozzle centrifuges were installed for testing.

Both the Wilsonville and Fort Lewis pilot plants continue to be operated under the sponsorship of U.S. ERDA. The Wilsonville pilot plant, having operated under process conditions simulating the Fort Lewis operation for SRC-I process, continues its operation with Utah Emery and Indiana V coals. Plans include study of the reaction conditions with various reaction volumes using half or full dissolver or dissolver by-passed. Direct injection of hydrogen recycle gas will also be examined. Several alternative solids separation techniques are being looked into which include use of hydroclones, centrifuges and solvent deashing techniques. Areas of operating improvements of the Funda filter are also included for future studies.

The Fort Lewis pilot plant has been operating under the SRC-II mode. Several material balance runs have been made with Kentucky #9 & 14 coals. Runs with other coals like Pittsburgh and Illinois coals are planned.

Published data from both pilot plants for operation in the SRC-I mode were examined with a view to evaluating the process conditions with various coals and developing a design basis for a commercial plant design presented later in this study.

1.2.2 Wilsonville Data (6.12.3 to .6, 6.12.8 to .11)

At Wilsonville the operation has been carried out with the following coals:

- Illinois #6 (Burning Star Mine)
- Pittsburgh #8 Seam, Loveridge Mine (W.Va.)
- Kentucky #9 & 14
- Illinois #6 (Monterey Mine No. 1)
- Amax, Belle Ayr (Wyoming, Sub-bituminous)

In Table 1-1, analyses (ultimate, proximate, sulfur forms, etc.) of these coals are included. Operating data of the reactor section for typical runs with the above coals are given in Table 1-2. These runs were selected as they represent mid-range operating conditions. Data for full dissolver were used in all cases except where noted. For Illinois #6 (Burning Star Mine) coal, three runs were selected -- one each for operating pressures of 1000, 1700 and 2400 psig, respectively. Coal feed rate was varied but reaction temperature was not. It may be noted that, in addition to precoat, a body feed was also used in these early runs.

Pittsburgh #8 coal was run under one set of conditions; namely, 1720 psig pressure and 853°F temperature. Run 35A was selected because it was the only run for which filtration data is published. Filtration included use of precoat and body-feed. Illinois #6, Monterey No. 1 Mine, high sulfur (3.9 to 4.4%) and high ash (10 to 11%) coal was run in 1975 at two different pressures. The solvent used was 350-750°F boiling point range. The coal was run again in 1976 with solvent of boiling range 450 to 780°F. The two runs selected from this later operation were made at two different slurry concentrations. The filter was operated without any body feed.

Wyoming sub-bituminous Amax, Belle Ayr Mine, coal was run in 1975 and again in 1976 -- each time with a solvent of different boiling range. One run was selected for each solvent used.

Kentucky #9 & 14 coal is the work horse of the pilot plants. For this study, the runs made in 1976 using a 450 to 780°F boiling range solvent were selected for comparison with the Fort Lewis operation. These runs were made using half of the dissolver volume to simulate the reaction volume at Fort Lewis. Other variations include those in slurry concentration and space rate.

A discussion of the effects of various coals on plant operation and yield characteristics, as summarized in various published reports, follows.

TABLE 1-1

TYPICAL ANALYSES OF GROUND COALS USED AT WILSONVILLE
(90% -200 Mesh)

	<u>Illinois No. 6</u> <u>Burning Star No. 2</u>	<u>West Virginia</u> <u>Pittsburgh No. 8</u>	<u>Kentucky 9 & 14</u> <u>Colonial Mine</u>	<u>Illinois No. 6</u> <u>Monterey No. 1</u>	<u>Wyoming Wyodak</u> <u>Belle Ayr, Amax</u>
<u>Proximate Analysis, Wt%(MF)</u>					
Volatile Matter	41.7	37.3	39.8	41.4	53.1
Fixed Carbon	45.9	54.4	49.8	48.4	41.0
Ash	12.4	8.3	10.4	10.2	5.9
Heating Value, Btu/lb	12,500	13,700	12,760	12,500	10,200
<u>Ultimate Analysis, Wt.%(MF)</u>					
Carbon	70.2	75.0	70.4	68.9	63.6
Hydrogen	4.8	5.5	5.1	5.0	3.5
Nitrogen	1.4	1.5	1.4	1.1	0.9
Sulfur	3.2	3.0	3.4	4.1	0.9
Chlorine	--	0.10	0.1	0.1	Trace
Ash	12.4	8.3	10.4	10.2	5.9
Oxygen	8.0	6.6	9.2	10.7	25.2
<u>Sulfur Forms, Wt.%</u>					
Pyritic	1.3	0.950	1.5	1.1	0.1
Sulfate	0.1	0.04	0.22	0.1	Trace
Organic	1.8	2.01	1.7	2.9	0.8
<u>Mineral Analysis of Ash, Wt.%</u>					
Silica	42.6	53.20	43.4	47.3	30.7
Ferric Oxide	18.6	15.2	32.5	18.2	5.0
Alumina	17.2	14.9	19.6	21.7	15.2
Lime	7.9	3.6	0.7	3.1	25.7
Magnesium Oxide	1.0	0.9	0.5	0.8	1.4
Sodium Oxide	0.4	1.4	0.2	1.3	2.5
Potassium Oxide	1.9	1.7	1.4	1.8	0.3
Titania	0.7	1.1	0.0	1.2	1.4
Sulfur Trioxide	5.6	7.6	0.9	4.1	15.6
Phosphorus Pentoxide	0.1	0.4	0.6	0.3	1.2
Undetermined	4.0	Trace	0.2	0.2	1.0

TABLE 1 -- 2
TYPICAL OPERATING CONDITIONS WITH VARIOUS COALS AT
WILSONVILLE PILOT PLANT

Pilot Plants	WILSONVILLE													
Type of Coal	◀ Illinois #6	Pgh. #8	◀ Illinois #6	Monterey #1	◀ Amax	◀ Kentucky 9-14								
Run Number	19 ⁽¹⁾	208 ⁽¹⁾	23 ⁽¹⁾	35A ⁽¹⁾	44MB2 ⁽³⁾	51MB ⁽³⁾	94 ⁽⁴⁾	95 ⁽⁴⁾	57BMB ⁽³⁾	100 ⁽⁴⁾	70-2 ⁽⁵⁾	75-1 ⁽⁵⁾	76-2 ⁽⁵⁾	81 ⁽⁵⁾
Operating Conditions														
Reaction Volume, Ft. ³														
Total	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	12.13	12.13	12.13	12.13
Dissolver	18.06	18.06	18.06	18.06	18.06	18.06	18.06	18.06	18.06	18.06	9.03	9.03	9.03	9.03
Coal Concentration, % MF Coal	25.0	24.0	38.0	34.0	25.0	25.0	24.7	36.0	20.0	25.1	38.8	38.4	24.0	37.8
Space Rate, lb/hr. ft. ³														
Total							22.0	41.0		23.0				
Dissolver	25	28	31	24	25	19	25.8	48.1	19.0	26.9	53.9	75.4	39.0	71.9
Coal Feed Rate, lb/hr. (MF)	480	540	626	514	501	392	466	468	390	486	477	679	351	647
Dissolver Outlet														
Temp. °F	831	831	831	853	870	856	855	864	854	858	828	823	824	852
Pressure, psig	1700	1000	2400	1720	1720	2400	2410	2400	2400	2410	1650	1650	1650	1650
Feed Gas														
Rate, MSCF/Ton MF Coal	20.9	20.35	20.52	19.32	21.69	54.7	43.9	17.7	50.94	39.7	24.3	22.9	22.3	19.5
Hydrogen Purity, Mole %	94.0	88.0	84.0	86.0	86	85	83.1	79.5	86.0	85.3	81.3	83.7	83.5	80.3
Operating Results														
Conversion, % MAF Coal	93.0	85.0	93.0	92.0	92.0	95.0	94.6	94.5	84.0	89.4	91.7	91.1	92.2	93.1
Hydrogen Consumption, % MF Coal	2.1	1.5	2.4	2.3	2.4	3.1	3.1	2.2	2.9	2.8	1.9	1.4	1.9	2.1
SRC Yield, % MF Coal	59.5	69.1	51.8	53.1	49.6	36.5	43.0	49.2	40.5	36.4	56.5	63.0	62.7	56.5
Sulfur in SRC, %	0.88	0.89	0.90	0.86	1.2	0.84	1.0	1.0	0.14	0.2	0.9	0.96	0.82	0.72
Gas Yield, % MF Coal														
CO-CO ₂	1.7	2.9	0.9	1.5	1.7	1.4	1.3	1.2	5.5	6.0	0.8	0.8	0.7	1.1
H ₂ S	2.0	1.5	1.6	1.4	3.3	2.5	3.2	2.1	0.6	0.2	1.2	1.8	1.2	1.8
C ₁							2.7	3.2		3.4	1.0	1.1	1.4	1.4
C ₂	5.8	4.8	3.6	6.7	7.6	9.3	2.5	2.8	8.8	2.4	0.7	0.6	0.6	0.8
C ₃							2.0	2.5		2.5	0.8	0.6	0.6	0.9
C ₄ -C ₅							1.4	2.3		3.7	0.5	0.4	0.4	0.7
Organic Liquid Yield % MF Coal														
C ₅ - 350	2.8	2.8	4.3	3.5	5.2	9.5	6.3	4.9	3.3	5.3	2.5	4.6	4.1	4.5
350 - 450	10.4	-3.0	16.0	10.1	15.7	17.7	12.4	11.9	11.7	6.6	2.9	1.7	6.5	0.2
450 - EP							3.8	1.4		8.5	13.7	6.6	3.4	14.0

(1) From Tables 1C, 2A, 2C, Wilsonville SRC Tech. Prog. Report No. 7
From Tables 3, 20, 22 Wilsonville Annual Tech. Prog. Report 1976

(2) Boiling Range 350 - 750°F

(3) From Tables 3.4.5 Wilsonville SRC Prog. Report No. 8

(5) Tables 3, 15 Wilsonville Second Quarterly Report 1976

1.2.2.1 Illinois #6 and Pittsburgh #8 coals:

Conversion was proportional to the hydrogen consumption to a certain degree. Both reaction temperature and pressure appear to have a strong effect on hydrogen consumption. Hydrogen consumption increased linearly with residence time. For Pittsburgh #8 coal, increase in slurry concentration decreased hydrogen consumption at the same temperature and pressure whereas for the same slurry concentration, hydrogen consumption increased with temperatures. Hydrogen consumption increased with increased hydrogen partial pressure.

For both coals, SRC yield decreased with hydrogen consumption whereas the converse was true for liquid and gas yields. For Pittsburgh seam coal, an increase in temperature from 850 to 870°F increased the gas and light organic liquid yields slightly at the expense of solvent production. Sulfur level in SRC decreased with increased hydrogen consumption. However, sulfur removal from Pittsburgh seam coal was more difficult than either the Illinois #6 or Kentucky #9 & 14 coals as evidenced by higher temperature and hydrogen consumption required to achieve the same degree of sulfur removal in Pittsburgh #8 coal. Organic sulfur removal ranged from 60 to 83%.

Oxygen removal was 60 to 85% for both coals. Depending on hydrogen consumption, between 0 to 40% of the total nitrogen in feed coal was found in the gas stream and the filter cake, distributed in approximately equal proportions. The balance of nitrogen was contained in SRC. The nitrogen in the gas stream appeared as ammonia. It was observed that nitrogen balance can be used to determine SRC yield with reasonable accuracy.

Reaction exotherm in the dissolver was a function of reaction temperature and the coal type. For Illinois #6 coal, the exotherm increased from 7,400 to 10,000 Btu/lb H₂ when temperature was raised from 830 to 840°F. For the Pittsburgh #8 coal to realize an exotherm of 10,000 Btu/lb H₂, the reaction temperature had to be raised to 855°F.

Collection of solids in the reactor tended to affect conversion at Wilsonville. This was eliminated when the exit hydrogen partial pressure and superficial velocity were raised. It was generally concluded that operating at conditions of high conversion resulted in stable operation.

Funda filter operation for solids removal gave specification SRC product at filtration rate of 15 to 25 gph/sq.ft. using a 0.25 lb body feed per lb of ash. The precoat level of 0.1 to 0.2 lb/sq.ft. of filter area was used. Hyflo-supercel as precoat material was not as effective as Johns-Manville Fibra-Flo 7-C.

Tests were conducted with Dorr-Oliver Doxie-5 and TML-4 hydroclone units. The test results were inconclusive.

On Table 1-3, the proximate and ultimate analyses of the SRC product of Illinois #6 and Pittsburgh #8 coals are listed. These products were solidified by water quench and hence had a very high moisture content. It may be noted that the SRC product from Illinois #6 coal gave a much lower heating value than SRC from any other coal.

1.2.2.2 Illinois #6 (Monterey), Amax Belle Ayr and Kentucky #9 & 14 Coals

Slurry Preheater: Observations made of tube wall and fluid temperatures in the slurry preheater showed that significant reaction, as evidenced by reaction exotherm, occurs in the preheater above 600°F. All coals, except Amax, reach a maximum at a fluid temperature of about 600°F when Δt between tube skin and fluid temperatures is plotted as a function of fluid temperature. There is a viscosity peak due to gel formation at about 600°F fluid temperature. The peak becomes less pronounced when the slurry concentration is reduced and cannot be detected below 25%. The viscosity peak was observed with all coals except Amax because only a dilute (20%) Amax coal slurry was used. The pressure drop in the preheater increased with coal concentration, coal slurry flow rate and gas rate. There appears to be little difference in pressure drop among several coals over the reaction pressure range of 1700 to 2400 psig. Since a significant part of conversion occurs in the preheater coil and the transfer line above 600°F, it is proper to include these volumes as part of the reaction volume to obtain a true picture of space-time relationships.

Reaction volume: For comparison with Fort Lewis operation, runs were made at Wilsonville with Kentucky #9 & 14 coals using a slurry concentration

TABLE 1-3
Analyses of SRC Produced from Various Coals at Wilsonville

Pilot Plant	Wilsonville							
Coal Type	Illinois 6	Pittsburgh 8	Kentucky 9 - 14		Illinois 6, Monterey		Wyoming, Amax	
Run Number	Run 23 (1)	Run 35 A (1)	Run 75 (4)	Run 76 (4)	Run 51A(2)	Run 95B (4) (Low Ash)	Run 578 (2)	Run 100 (4)
Proximate Analysis, Wt. %								
Volatile Matter	56.14	56.19	50.30	58.77	71.52	85.14	51.51	77.45
Fixed Carbon	31.04	43.04	44.58	41.09	27.64	14.79	48.1	21.65
Ash	---	---	5.12 ⁽³⁾	0.14	---	0.07	0.39	0.90
Moisture	29.0 ⁽⁵⁾	29.0 ⁽⁵⁾	---	---	0.01 ⁽⁶⁾	---	---	---
High Heating Value, BTU/lb.	13,652	15,815	14,806	15,795	15,825	15,770	15,910	15,726
Ultimate Analysis, Wt. %								
Carbon	75.93	87.22	81.46	85.95	86.99	86.65	88.32	87.71
Hydrogen	4.85	5.66	5.78	6.01	5.92	5.91	5.64	5.59
Nitrogen	1.43	1.61	1.72	1.95	1.94	1.83	1.71	1.67
Sulfur	1.71	0.94	1.45	1.01	0.82	1.21	0.13	0.26
Chlorine	0.06	0.02	0.03	0.01	--	0.07	--	0.02
Ash	12.79	0.77	5.12	0.14	0.2	0.07	0.14	0.90
Oxygen	3.23	3.78	4.44	4.93	4.13	4.26	4.06	4.87
Melting Point, °F	390	340	328	500	298		300	330
Sulfur Forms, Wt. %								
Pyritic	0.03	0.01	0.07	0.01	0.07	< 0.01	0.01	< 0.01
Sulfate	0.07	0.02	0.02	0.01	0.01	< 0.01		< 0.01
Organic	0.94	0.86	1.14	1.0	0.7	1.19	0.11	0.26
Sulfide	0.67	0.05	0.22	0.01	0.04	0.02	0.01	< 0.01

(1) Table 2G, Wilsonville SRC Tech. Report No. 7

(4) Table 35, Wilsonville Annual Tech. Progress Report, 1976

(2) Table 49 Wilsonville SRC Tech. Report No. 8

(5) Product Water Quenched Directly

(3) Filter by-passed partially

(6) Product solidified by indirect cooling

of 38.5%, gas rate of 20 MSCF/ton dry coal, feed gas hydrogen purity of 85% and a pressure of 1650 psig. Further similarity in operation was achieved by reduction in dissolver volume and increasing the ratio of preheater to dissolver volume. Also the process solvent boiling range was adjusted to 450 to 780°F.

The flow pattern in the preheater section can be approximated by the plug-flow model. The increase in the ratio of preheater to dissolver volume would, in effect, increase the proportion of plug flow volume and residence time. For a given space-time, conversion increased with a decrease in dissolver volume provided solvent hydrogenation is sufficient. A realistic model for the SRC reaction system, therefore, would be a plug flow reactor followed by a back-mix reactor.

Conversion of Kentucky #9 & 14 coal increased

- as the ratio of preheater to dissolver volume was increased
- with the use of solvent mixture with greater percentage of higher boiling components above 550°F.

Run No. 81 shows that at half dissolver volume, giving a preheater to dissolver ratio of 0.33 and using the heavier 450 to 780°F boiling range solvent, high conversion was realized. This may be due to higher effective solvent to coal ratio in the dissolver because of the reduced vaporization at the dissolver temperature as compared to the 350 to 750°F boiling range solvent used in earlier runs. This may also be due possibly to higher hydrogen-transfer capacity which the heavier solvent may have.

Increase in plug flow results in

- decrease in C₁-C₅ gases and light organic oils
- increase in intermediate product (heavy solvent)
- decrease in SRC yield.

It was also observed that, during plug flow reaction, the solvent contributes to coal hydrogenation. The solvent is then rehydrogenated in the dissolver. Therefore, there is an optimum ratio of plug-flow to back-mix regime for a given set of reaction conditions.

Hydrogen consumption: Hydrogen consumption was observed

- to increase with increase in reaction temperature,
- to increase with increased slurry concentration, at the same space rate, and
- to increase with increased percentage of plug flow volume for a given space-time (a certain degree of solvent hydrogenation must take place to sustain the stability of the reaction).

Hydrogen consumption increases with space-time as shown in Figure 1-3. Hydrogen consumption appears to increase almost linearly with an increase in hydrogen partial pressure in the 1600 to 2400 psig dissolver pressure range. Hydrogen consumption does not vary by more than 0.5% for different coals at the same conditions.

Reaction exotherm has an effect on hydrogen consumption. There appears to be a significant increase in hydrogen consumption using Amax and Monterey (Illinois #6) coals at the same conditions and the same reaction exotherm as compared to the runs made in 1975.

Hydrogen consumption increased when hydrogen partial pressure was increased as seen by increase in gas flow rate in Runs 94 and 95 for Monterey coals. For both Kentucky #9 & 14 and Monterey coals, hydrogen consumption increased 0.5 to 1% when slurry concentration was increased from 25 to 38.4%. For Amax coal there is not sufficient conclusive data for the effect of slurry concentration on hydrogen consumption.

There is insufficient data to separate the effect of solvent composition on hydrogen consumption for Monterey and Amax coals. For the same hydrogen consumption rate the solvent boiling range does not have any effect on conversion or SRC yield.

The higher the space rate, the better the SRC yield. Use of high space rate would reduce hydrogen consumption to the 1.4 - 1.8% range.

MONTEREY COAL, 2400 PSIG
450-800°F SOLVENT	KENTUCKY 9 AND 14 COAL, 1700 PSIG
⊙ FULL DISSOLVER VOLUME
855-864°F, 14.7% PLUG FLOW	— FULL DISSOLVER, 38.5% SLURRY
850°F REACTOR TEMP.
350-800°F SOLVENT
□ HALF DISSOLVER VOLUME
855-861°F, 25.6% PLUG FLOW	— HALF DISSOLVER, 38.5% SLURRY
850°F REACTOR TEMP.
450-800°F SOLVENT
△ DISSOLVER BYPASSED
823°F, 100% PLUG FLOW	--- HALF DISSOLVER, 38.5% SLURRY
825°F REACTOR TEMP.
350-800°F SOLVENT

Figure 1-3. Effect of Space Time on Hydrogen Consumption

Increased hydrogen consumption results in

- increase in conversion
- increase in gas and liquid yields
- decrease in SRC yield
- increase in desulfurization

For Kentucky #9 & 14 coal, the yields of organic liquids and gases increased linearly with hydrogen consumption. Effects of hydrogen consumption on conversion, exotherm, sulfur in SRC and SRC yield are shown in Figure 1-4.

Conversion and yields: For all three coals conversion increases with increased hydrogen consumption, although the relationship becomes non-linear as the percent hydrogen consumed increases. Conversion of 92 to 94% of MAF coal feed was achieved with Kentucky #9 & 14 and Monterey coals with about 2% hydrogen consumption; whereas, for Amax coal a 90% conversion was achieved with a 3% hydrogen consumption.

In the runs made with Monterey coal using 350 to 750°F boiling range solvent, it was observed that at 1700 psig pressure increased reaction temperature (860 to 870°F) and increased hydrogen feed rate (54.7 MSCF/ton MF coal) were needed to get good conversion (> 92%) and desulfurization. Hydrogen consumption was 3.1%. However, when run at 2400 psig with a heavier solvent Monterey coal seemed to be less sensitive to hydrogen consumption or increased space rate. These variations may be due to variations in compositions of feed coals used at different times.

Amax coal with 0.3% sulfur in early runs yielded a product with 0.1 to 0.2% sulfur under conditions of high pressure, 2400 psig, and high temperatures, 855°F. The solvent had a boiling range of 350 to 750°F. Conversion was 85% and hydrogen consumption 2.9% MF coal. With higher boiling solvent in the later runs, Amax coal gave higher conversion. This may also be due to difference in feed coal compositions. Within the range of the pilot plant operations, the SRC yield appears to reach a maximum at a hydrogen consumption of 1 to 2% of MF coal for the eastern bituminous coals, and 2 to 3% of the MF coal for the western sub-bituminous coal. The optimum range appears to increase with an increase in the oxygen content of the coal. For the bituminous coals,

FIGURE 1-4
EFFECTS OF HYDROGEN CONSUMPTION
(ON COAL CONVERSION, REACTOR EXOTHERM, SULFUR IN SRC AND SRC YIELD)

1. ON COAL CONVERSION

2. ON REACTOR EXOTHERM

3. ON SULFUR IN SRC

4. ON SRC YIELD

it appears that the optimum yield would occur at milder reaction conditions (high space rate, low temperature) as compared to the Amax-Bellé Ayr coal. This could be due to the higher conversion achieved for the bituminous coals at low hydrogen consumption.

Comparison of yields for the three reactor configurations (full dissolver, half dissolver and by-passed dissolver) indicates that the ratio of plug flow volume to dissolver volume has a significant influence on the yield pattern. The following general observations can be made:

- 1) Yield of C₁-C₅ gases and light organic liquids decreases as dissolver volume is decreased in proportion to the preheater;
- 2) Yield of heavy solvent increases with decreased dissolver volume.

At the same level of hydrogen consumption, the yield of solvent appears to be higher for the half-dissolver operations. This is probably because a greater percentage of the hydrogen consumed is used in generating liquid by cracking SRC, and less is used in the production of gas by cracking the solvent.

At a constant hydrogen consumption, the SRC yields for each configuration appear to be about the same within the range of space rates used, nor is there any obvious difference in SRC yields due to changes in process solvent boiling range.

Within the range of the pilot plant operations, the yields of gases and liquids appear to increase linearly with hydrogen consumption at a constant hydrogen pressure, temperature and reaction configuration. For Monterey (Illinois #6) coal, an increase in pressure from 1700 to 2400 psig appeared to increase the selectivity of the reaction toward solvent production. At a constant hydrogen consumption, SRC yield was lower at 2400 psig. Hydrocracking of the liquids to gases was also reduced at the higher pressure.

Desulfurization: In general, organic sulfur removal depends upon the severity of reaction. An increase in severity results in greater sulfur removal. The severity of reaction conditions can be increased by increasing one or more variables such as temperature, pressure, feed gas rate, gas purity, or residence time. Since it is known that hydrogen consumption also increases with severity, it is convenient to correlate organic sulfur in SRC product with hydrogen consumption.

The tabulated data indicate that there are other factors which contribute to the degree of desulfurization. For example:

- o hydrogen transfer capability of the solvent may improve sulfur removal, e.g., Runs 81 on Kentucky #9 & 14 coal, using the higher boiling range process solvent;
- o conditions which tend to decrease the amount of hydrocracking of SRC tend to decrease the amount of sulfur removal.

Deoxygenation and Denitrogenation: During coal hydrogenation, oxygen and nitrogen react with hydrogen to form water and ammonia, respectively. Oxygen also reacts with carbon to form carbon monoxide and carbon dioxide. Oxygen removal from the feed coal, as a result of these reactions, varied from 58% to 80%. An increase in hydrogen consumption, because of more severe reaction conditions, removes additional oxygen.

Oxygen and nitrogen removals are calculated as the weight percent of the element in the feed coal which is not contained in the SRC. Similar to sulfur removal, oxygen and nitrogen removals for Monterey (Illinois #6) coal at 1700 psig are close to those reported for Kentucky #9 & 14 at similar conditions.

Nitrogen is more difficult to remove than oxygen because the reaction between nitrogen and hydrogen does not take place easily. The amount of nitrogen removed is quite small and considerable error can be expected in the calculated value. Nitrogen removal from the feed coal ranges from 3 to 35%. About 30 to 50% of the nitrogen removed shows up as ammonia.

Product Analyses: Table 1-3 includes analyses of SRC product from these three coals. They seem to be identical regardless of the mother coal.

1.2.2.3 Filtration

The undissolved solids in the coal solution are removed by the Funda Filter. The Funda filter is a pressure-leaf filter which originally had 20 horizontal circular leaves with a total effective area of 54 sq. ft. Since

July 1976, additional leaves were installed to increase the surface area to 100 sq. ft. The filter is designed to operate at temperatures of 450-550°F and pressures of 150-200 psig. The system is pressurized with nitrogen. Filter operation is programmed to run in a cyclical batch mode and is automatically controlled by a Tenor programmer. The total cycle requires 90 minutes, of which 30 minutes are for filtration.

A precoat of filter aids like Johns-Manville type Fibra-Flo 7C (containing 7-1/2% asbestos) standard Super Cel and Hyflo Super-Cel is applied. Precoat thickness of 1/8" is obtained with about 0.25 lbs of precoat per sq.ft. In the initial operation of the filter, additional filteraid was incorporated in the filter feed. This need has been eliminated as more experience was gained with the operation. Celite 560 (asbestos-free) was tried as a precoat. Problems of screen blinding occurred with 60 x 60 mesh screens. Fibra-Flo 7-C was used for good solids removal with 60 x 60 mesh screens. With 80 x 80 mesh screens, Celite 560 gave improved performance. During precoating, a ΔP of about 40 psi is observed. The filter screens ranged from 120 x 330 mesh to 60 x 60 mesh.

After precoating, filtration of the process slurry is established without the loss of pressure on the filter so as not to disturb the precoat. Feed rates are in the range of 15-20 gpm to give a filtration rate of about 16-22 gallons per hour per square foot. Final pressure drops after 30-60 minutes of filtration range from 35-65 psi. The quantity of filtrate per cycle varies from 150-400 gallons. Filtration temperatures have varied from 450-550°F, with most operations at about 500°F.

After filtration, nitrogen is blown through the filter cake for 2-3 minutes to reduce the amount of liquid in the cake. The filter cake is then washed with wash solvent for a period of 3-5 minutes. At a wash rate of 15-20 gpm, the residual liquid after the nitrogen blow should be replaced 3-4 times.

On completion of the wash step, the feed in the filter is blown back to the filter feed tank with nitrogen. The filter cake is vacuum dried on

filter leaves for 5 minutes at 1 psia and solvent content of the cake is reduced to 5-10 wt.%. The dry cake is discharged by spinning the leaves at 400 rpm for four 30-second periods. Tangential nitrogen blow helps cake discharge. Operating conditions as well as downtime cycle (i.e., all operations other than actual filtration time) are listed in Table 1-4. The data is for Kentucky #9 & 14 coal.

Filtration was changed from flow to pressure control. Pressure control prevents compression of filter cake. Assuming that the medium resistance is small, a relation between volume of filtrate collected as a function of time is expressed as:

$$T = C_1 V^2 \quad (1.1)$$

where

$$C_1 = \frac{C \mu \mathcal{L}}{2A^2 P g_c}$$

C = Pounds of solids deposited per cu ft of filtrate

μ = Viscosity of filtrate, lb/ft-sec

$\mathcal{L}$ = Specific resistance of cake, ft/lb_m

A = Area of filter, ft²

ΔP = Pressure drop lb/ft²

g_c = Newton's conversion factor, 32.1 ft lb/lb-sec²

V = Total volume of filtrate collected in time T secs, ft³

The value of $\mathcal{L}$ was estimated to be ≈ 10 ft/lb_m at 25 psi and is known to be a function of ΔP .

$$\mathcal{L} = \mathcal{L}_0 \Delta p^S \quad (1.2)$$

$\mathcal{L}_0$ and S are empirical constants.

Filtration rate was found to be proportional to pressure drop unlike compressible cake. Filtration rate was found to change with reaction conditions and type of coal, and may be attributed to change in viscosity of filter feed with different coals. Filtration rate can be expressed by the model:

$$q.L = \text{Constant} \times (\Delta P)^{1-S} \quad (1.3)$$

q = Average filtration rate, ft³/sec

L = Thickness of cake, ft

ΔP = Pressure drop, lb/ft²

S is found to have the same value as in equation 1.2.

For Kentucky coal, the value of α_0 was calculated to be 2.36×10^{11} and the value of S to be 0.39. A plot of cake resistance as a function of filtration pressure for several coals is given in Figure 1-5. Lowest specific cake resistance and highest compressibility were obtained from Amax coal filter cake, perhaps due to coarser residual particles of unconverted bituminous coal and the altered coal minerals.

TABLE 1-4

FUNDA FILTER OPERATING CONDITIONS
AND
DOWNTIME (KY #9 & 14 COAL)

1. Operating Conditions

Average filtration rate, gph/sq. ft.	10-20
Filtration time, min	15-30
Cycle time, min	70-90
Filter System Pressure, psig	115
ΔP during precoat, psi	4-40
ΔP during filtration, psi	10-60
Precoat loading, lb/sq.ft.	0-0.25
Filter cake, lb/cycle	100-200
Filter cake, lb/sq.ft.	1.5-3.3

2. Downtime (other than filtration time)

Operation	<u>Time, min</u>
Pressurize	3
Precoat fill	5
Precoat	8
Wash fill	5
Wash	4
Wash drain	3
Cake blow	3
Depressurize	5
Vacuum dry	5
Discharge	4
Standby	<u>15</u>
Total	60

Figure 1-5. Specific Resistance vs Filtration Pressure Drop

1.2.3 Fort Lewis Data (6.13.13)

Fort Lewis pilot plant operation in SRC-I mode can be divided in three periods:

- Material Balance Period
- Production Run Period
- Filtration Test Period

1.2.3.1 Material Balance Period

During the SRC-I mode of operation of the pilot plant, eleven material balance runs were made

- to obtain quantitative process yields
- to determine the effects of various operating conditions on the yields, and
- to define operating conditions which optimize the SRC-I process from both process and mechanical standpoints.

A blend of Kentucky #9 & 14 coal seams was used throughout these runs. Analysis of the coal used is given in Table 1-5.

A list of the most important process conditions studied are given in Table 1-6. Five coal space rates from 30 to 100 lbs/hr x ft³, five temperatures between 830 and 870°F, and three pressures between 1000 and 1500 psig were studied. The major emphasis of the program was toward higher coal space rates and the study of effects of reactor temperatures. It was believed that relatively small changes in the dissolver temperature would generate substantially greater levels of reactivity resulting from the temperature dependency of the reaction rate constants. The range of space rates used would give a corresponding range of residence times between 0.92 and 0.27 hours.

Yield data were obtained from liquid level changes in plant vessels and accumulations, on-line gas flow-rate and gas chromatographic measurements and laboratory analyses of various product samples. This information was used to calculate average product compositions, an overall process yield material balance, etc. These yield data are also listed in Table 1-6. A typical analysis of SRC produced at Fort Lewis is given in Table 1-7.

TABLE 1-5

TYPICAL ANALYSIS OF GROUND COAL USED AT FORT LEWIS

(90% -200 Mesh)Kentucky 9 & 14
Colonial MineProximate Analysis, Wt.%

Volatile Matter	37.7
Fixed Carbon	50.39
Ash	10.13

<u>Moisture</u>	1.78
-----------------	------

<u>High Heating Value, BTU/lb</u>	12,929
-----------------------------------	--------

Ultimate Analysis, Wt.% (Dry)

Carbon	71.82
Hydrogen	5.02
Nitrogen	1.33
Sulfur	3.68
Chlorine	0.04
Ash	10.31
Oxygen	7.8

Sulfur Forms, Wt.%

Pyritic	2.09
Sulfate	0.18
Organic	1.4

Mineral Analysis of Ash, Wt.%

Silica	39.44
Ferric Oxide	31.47
Alumina	20.71
Lime	2.13
Magnesium Oxide	0.69
Sodium Oxide	0.40
Potassium Oxide	0.40
Titania	0.90
Sulfur Trioxide	1.73
Phosphorus Pentoxide	0.22
Undetermined	0.40

Table 1-6
Operating Conditions at Fort Lewis Pilot Plant For
SRC-1 Mode of Operation (2)

Type of Coal	KENTUCKY 9 & 14										
	1	2	3	4	5	6	7	8	9	10	11
Run Number											
Operating Conditions											
Reaction Volume, Ft. ³											
Total	92	92	51	51	51	51	51	51	51	51	51
Dissolver											
Coal Concentration, % MF Coal	38	39	38	39	38	38	38	39	39	38	39
Space Rate, lb/hr. ft. ³											
Total											
Dissolver	49.5	29.0	75.2	77.9	97.6	98.5	98.8	79.7	91.0	72.8	73.7
Coal Feed Rate, lb/hr. (MF)	4551	2666	3821	3959	4956	5002	5020	4050	4625	3699	3745
Dissolver Outlet											
Temp. °F	851	848	870	844	849	870	850	846	859	842	848
Pressure, psig	1528	1489	1496	1499	1488	1483	1471	1484	1478	1027	1261
Feed Gas											
Rate, MSCF/Ton MF Coal	14.0	21.3	18.2	17.7	14.2	13.4	13.2	17.0	14.9	21.5	20.8
Hydrogen Purity, Mole %	94.8	97.1	93.5	93.8	92.0	90.7	91.4	94.1	92.5	96.0	94.2
Operating Results											
Conversion, % MAF Coal	93.4	95.2	92.9	94.2	93.7	93.5	94.3	94.6	94.1	93.7	93.9
Hydrogen Consumption % MF Coal	2.5	2.7	2.1	2.0	2.0	2.0	1.9	2.4	2.1	2.1	2.3
SRC Yield, % MF Coal	58.3	57.5	58.6	64.0	67.3	65.9	65.6	63.0	64.2	65.4	61.1
Sulfur in SRC %	0.87(1)	0.57(1)	0.72(1)	0.85(1)	0.88(1)	0.78(1)	0.77(1)	0.66(1)	0.70(1)	0.75(1)	0.74(1)
Gas Yield, % MF Coal	8.7	8.1	11.8	5.8	4.9	7.4	6.5	5.9	7.3	7.3	8.4
Organic Liquid Yield % MF Coal	14.7	17.7	8.2	12.3	8.6	6.7	8.8	13.5	10.0	6.9	9.1
Solvent (450-800°F) % MF Coal	0.1	-3.9	-4.0	2.9	-1.2	-2.6	-1.2	4.4	-0.2	-1.2	1.2

(1) Laboratory Produced SRC

(2) Data from Tables 21, 27-38, 49-59 R&D Report No. 53, Interim Report 22

TABLE 1-7

TYPICAL ANALYSIS OF SRC PRODUCED AT FORT LEWIS

Ultimate Analysis (Dry)	Wt. %
Carbon	87.24
Hydrogen	5.77
Nitrogen	2.15
Sulfur	0.75
Chlorine	--
Ash	0.16
Oxygen	3.93
Melting Point, °F	324

Since the filtration area was bypassed during these eleven runs, no filtration data was recorded. Also, the ash content of unfiltered SRC is not included in Table 1-6.

It was established that a desirable process yield structure could be obtained at higher space rates and lower residence times than originally planned. Runs 5 and 7 were duplicate runs at the highest space rate (100 lb/hr x ft³) and Runs 4 and 8 were duplicate runs at a moderate space rate (75 lb/hr x ft³). A comparison of these duplicate runs indicates good reproducibility. Runs 1, 4, 8 and 11 demonstrate that the process can run in solvent balance.

Runs 3, 5 and 6 show the combined effect of higher space rates and temperatures. At high space rates, lower hydrogen feed rates are required for same hydrogen consumption, conversion and SRC yield. Higher temperature gives high gas yield and higher space rate yields higher SRC yield. Runs 10 and 11 illustrate the effect of reactor pressure and determine the lower limit of dissolver pressure.

Statistical analysis of the SRC-I yield structure and process conditions was made. Process variables studied were:

- Coal space rate
- Total hourly space rate
- Process solvent yield
- Hydrogen consumption
- Dissolver outlet temperature
- Inverse dissolver outlet temperature
- Inverse total hourly space rate.

Of these, the total hourly space rate (THSR) and dissolver outlet temperature were found to be the most significant in modeling the various components. Models were developed by regression analysis using data from Runs 1 to 9, except for liquid yields of Runs 1 to 3. Data from Runs 10 and 11 were not used due to different pressures employed. The models for various components are listed in Table 1-8. Yields of CO, water, mineral residue and unreacted

TABLE 1-8

MULTIPLE LINEAR REGRESSION MODELS FOR SRC-I⁽¹⁾
 1500 psig - Kentucky Coal - 1.6/1 Solvent to Coal Ratio

YIELD REGRESSION MODELS
 (Yield as Percent Moisture Free Coal Feed)

Hydrogen	- 3.685	+ 3.919 x 10 ⁻³ (THSR)	+ 7.952 x 10 ⁻⁴ (T)
Methane	- 38.088	- 5.782 x 10 ⁻³ (THSR)	+ 4.917 x 10 ⁻² (T)
Ethane:	- 18.185	- 3.396 x 10 ⁻³ (THSR)	+ 2.350 x 10 ⁻² (T)
Propane:	- 16.870	- 2.803 x 10 ⁻³ (THSR)	+ 2.165 x 10 ⁻² (T)
Butane:	- 31.396	- 3.324 x 10 ⁻³ (THSR)	+ 3.830 x 10 ⁻² (T)
Carbon Dioxide:	- 6.999	- 1.304 x 10 ⁻³ (THSR)	+ 9.723 x 10 ⁻³ (T)
Light Oil:	- 41.767	- 3.616 x 10 ⁻² (THSR)	- 6.410 x 10 ⁻² (T)
Wash Solvent:	58.670	+ 4.609 x 10 ⁻² (THSR)	- 7.544 x 10 ⁻² (T)
Process Solvent:	80.702	- 8.211 x 10 ⁻² (THSR)	- 7.088 x 10 ⁻² (T)
SRC:	135.130	+ 5.456 x 10 ⁻² (THSR)	- 9.793 x 10 ⁻² (T)
Total C ₁ -C ₄ :	-103.465	- 1.520 x 10 ⁻² (THSR)	+13.039 x 10 ⁻² (T)
Total Liquid:	97.617	- 7.217 x 10 ⁻² (THSR)	- 8.224 x 10 ⁻² (T)

(1) Table 23, Ref. 6.13.13

coal were not correlated for various reasons. The dependent variables used in the correlations are shown on Table 1-9. The actual yields and those predicted by the corresponding models are given in Table 1-10. It may be seen that the results indicate good predictions from most of the models. The models developed for total liquid, total gas, SRC yield and the model developed for hydrogen consumption are shown with actual data used in model formation as shown in Figure 1-6.

Some of the significant conclusions, based upon data from the material balance runs for the reaction system, are as follows;

- Higher coal space rates (lower reactor residence times) increase the SRC yield, decrease the total gas yield and decrease the total solvent yield.
- Increased dissolver temperatures decrease the SRC yield, increase the total gas yield and decrease the total solvent yield.
- Lower dissolver pressure promotes increased gas yields and reduces total solvent yields.
- The reaction may have been hydrogen limited.
- The water yields may not be representative of actual yields since they were calculated on a forced oxygen balance.
- The individual solvent yields (light oil, wash solvent and process solvent) were difficult to determine because of poor distillations and analysis, particularly during the first three material balance tests.
- No substantial effect was noted when the reactor volume was reduced from 90 ft³ to 50 ft³ -- i.e., effects of reactor geometry were not discernible.
- A substantial increase in dissolver temperature was recorded in the first four feet of length for each material balance run.
- The hydrogen consumption remained relatively constant and was not greatly affected by coal space rate or dissolver temperature.

TABLE 1-9

SRC-I DEPENDENT VARIABLES USED IN REGRESSION ANALYSIS

Independent Variables			Dependent Variables Yield, Percent Moisture Free Coal											
Run #	THSR	T	H ₂	CH ₄	C ₂ H ₆	C ₃ H ₈	C ₄ H ₁₀	Total HC Gas	CO ₂	LO	WS	PS	Total Liquid	SRC
1	136.6	851	-2.5	2.2	1.3	1.1	0.8	5.4	1.2	---	---	---	---	58.3
2	77.9	848	-2.7	2.3	1.5	1.2	0.5	5.5	1.1	---	---	---	---	57.5
3	208.2	870	-2.1	2.7	1.6	1.6	2.0	7.9	1.2	---	---	---	---	58.6
4	209.7	844	-2.0	1.5	0.9	0.9	0.4	3.7	1.0	4.3	5.1	2.9	12.3	64.0
5	264.1	849	-2.0	1.3	0.8	0.6	0.2	2.9	0.9	2.6	7.2	-1.2	8.6	67.3
6	264.9	870	-2.0	2.2	1.3	1.0	0.4	4.9	1.1	4.1	5.2	-2.6	6.7	65.9
7	264.9	850	-1.9	1.4	1.0	0.9	0.4	3.7	1.0	3.7	6.3	-1.2	8.8	65.6
8	210.3	846	-2.4	1.4	1.0	0.9	0.4	3.7	0.8	5.1	4.0	4.4	13.5	63.0
9	239.4	859	-2.1	2.1	1.2	1.1	0.5	4.9	1.0	5.1	5.1	-0.2	10.0	64.2

TABLE 1-10

MODEL PREDICTIONS VS. ACTUAL MEASURED COMPONENT YIELDS

(EXPRESSED IN PERCENT OF M.F. COAL FEED)

1500 PSIG - KENTUCKY COAL - -1.6/1 SOLVENT TO COAL RATIO

Run No.	-HYDROGEN-		-METHANE-		-ETHANE-		-PROPANE-		-BUTANE-		-C ₁ -C ₄ Gas-	
	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual
1	- 2.47	-2.5	2.17	2.2	1.35	1.3	1.17	1.1	0.74	0.8	5.52	5.4
2	- 2.71	-2.7	2.37	2.3	1.48	1.5	1.27	1.2	0.82	0.5	5.92	5.5
3	- 2.18	-2.1	2.69	2.8	1.55	1.6	1.38	1.6	1.23	2.0	6.81	7.9
4	- 2.19	-2.0	1.41	1.5	0.94	0.9	0.81	0.9	0.23	0.4	3.40	3.7
5	- 1.97	-2.0	1.34	1.3	0.87	0.8	0.77	0.6	0.24	0.2	3.22	2.9
6	- 1.96	-2.0	2.37	2.2	1.36	1.3	1.22	1.0	1.04	0.4	5.95	4.9
7	- 1.97	-1.9	1.38	1.4	0.89	1.0	0.79	0.9	0.28	0.4	3.34	3.7
8	- 2.19	-2.4	1.50	1.4	0.98	1.0	0.85	0.9	0.31	0.4	3.65	3.7
9	- 2.06	-2.1	1.97	2.1	1.19	1.2	1.05	1.1	0.71	0.5	4.90	4.9

Run No.	-CO ₂ -		-LT. OIL-		-WASH SOLV.-		-PROC. SOLV.-		TOTAL LIQUIDS		-SRC-	
	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual
1	1.10	1.2	*	*	*	*	*	*	*	*	59.24	58.3
2	1.14	1.1	*	*	*	*	*	*	*	*	56.33	57.6
3	1.19	1.2	*	*	*	*	*	*	*	*	61.29	59.8
4	0.93	1.0	4.75	4.3	4.66	5.1	3.66	2.9	13.07	12.3	63.91	64.0
5	0.91	0.9	3.10	2.6	6.79	7.2	-1.16	-1.2	8.74	8.6	66.39	67.3
6	1.11	1.1	4.42	4.1	5.25	5.2	-2.71	-2.6	6.95	6.7	64.33	65.9
7	0.92	1.0	3.14	3.7	6.76	6.3	-1.80	-1.2	8.60	8.8	66.34	65.6
8	0.95	0.8	4.86	5.1	4.54	4.0	3.47	4.4	12.86	13.5	63.75	63.0
9	1.04	1.0	4.64	5.1	4.90	5.1	0.15	-0.2	9.70	10.0	64.07	64.2

FIGURE 1-6
EFFECT OF DISSOLVER OUTLET TEMPERATURE AND
TOTAL HOURLY SPACE RATE ON YIELDS AND HYDROGEN CONSUMPTION

(1) MODEL FOR GAS YIELD

(2) MODEL FOR SRC YIELD

(3) MODEL FOR TOTAL LIQUID YIELD

(4) MODEL FOR HYDROGEN CONSUMPTION

Data on the preheater operation led to the following observations:

- The effects of changing preheater outlet temperature or solvent/coal ratio are unknown.
- Increasing the heat flux during preheating reduced the pressure drop through the preheater.
- The majority of the pressure drops through the preheater occur between tube turn 30 and 40. The pressure drops averaged about 50 to 60 psi.

1.2.3.2 Production Run Period

Following the material balance runs a production run was scheduled to produce 3000 tons of specification grade SRC product for a large burn test at Plant Mitchell in Albany, Georgia. The first 700 tons shipped analyzed 0.34 wt.% ash and 0.73 wt.% sulfur. The remaining 2300 tons shipped analyzed 0.16 wt.% ash and 0.74 wt.% sulfur. The production run lasted over a year and a great deal of progress was made toward defining and solving many process and mechanical problems.

1.2.3.3 Filtration Test Period

Even though two filters are installed at the pilot plant, one with an 80 ft² filter area and the other a 40 ft² filter area, the tests were conducted on the smaller filter, Filter B, which had an actual filter area of 41.69 ft². Filter B was equipped with a Johnson screen, which is a slotted screen with trapezoidal shaped bars, which potentially reduces screen blinding as compared to Dutch weave screens.

Filtration rate can be expressed in terms of three resistances:

- Precoat Resistance - resistance due to filter aid
- Cake Resistance - resistance due to layer of solids removed from filter feed
- Interface Resistance - resistance due to penetration of solids into the precoat.

TABLE 1-11
FILTRATION TEST RUNS
(KENTUCKY #9 & 14 COAL)

Base Conditions

1. Filtration Base Conditions

Precoat	500 lbs, Speedex
Base Coat	10 lbs, 11-C
Knife Advance	2 mils/min
Drum Speed	1.7 RPM
Drum Submergence	30% diameter
Vat Pressure	110 PSIG
Pressure Differential	30 PSI
Filter Temperature	490°F
Slurry Feed to Filter	25,000 lbs/hr.
Cake Wash Rate	850 lbs/hr wash solvent

2. Reaction Conditions

Coal Feed Rate	2500-3500 lbs/hr
Solvent to Coal Ratio	1.5/1
Dissolver Outlet Temp.	850-860°F
Reactor Pressure	1500 PSIG

The objectives of the tests were to observe the effects of operating variables on the resistance parameters and optimization. In all, twelve (12) runs were conducted. The effects of seven variables were tested with only one variable being tested in a given run. These variables were:

- Precoat Application Procedures
- Precoat Grade (Speedplus: 8.8-9.4 microns; Speedex: 10-12 microns)
- Knife Advance Rates (1 to 5 mils/min)
- Drum Speed (1 to 6 rpm)
- Drum Submergence (9% to 40% diameter submerged)
- Pressure Drop
- Cake Wash Rate

For comparison and data analysis, the parameters chosen were:

- Filtration rate
- Solids removal rate per unit of precoat
- Gas flow rate through the filter

The base conditions, chosen to supposedly represent mid-range operating conditions, are listed in Table 1-11.

It was observed that there was some variability in precoat permeability due to the precoat application procedures. Data show that filtration rates and gas flow rates tend to be higher at the end of a run than early stages of the run. The average filtration rates for base conditions in the runs in which Speedplus was used as a precoat material appear to be higher than Speedex precoat runs, though no definite conclusion was possible. Precoat thickness appears to have an effect on filter performance.

Filtration rate increases with increased Knife advance rates. However, it approaches an asymptotic value at high Knife advance rates. Filter efficiency decreased as Knife advance increased. This implies that more precoat is consumed in producing the same quantity of filtrate at high Knife advance rates than at low Knife advance rates. Knife advance rates seem to have interaction with other operating variables.

Filtration rate increased with increased drum submergence indicating that the filter cake is not completely blinding the precoat. The rate, however, approached some maximum rate.

Filtration rates, when plotted as a function of drum speed with Knife advance rate as a parameter, show that highest drum speed gave highest filtration rate and highest Knife advance rates also gave highest filtration rates. These results indicate that highest drum speed and Knife advance rates should be utilized.

For the range of cake wash rate studied it was observed that increasing the amount of cake wash did not increase the filtration rate.

Effects of pressure differential and Knife advance rate showed that an increase in ΔP from 30 to 40 psi increased the filtration rate at any Knife advance rate; however, increase in Knife advance rate at ΔP of 40 psi gave greater filtration rates than at ΔP of 30 psi. However, solids removal efficiency decreased with increase in Knife advance rate. Based on the test data, it was concluded that the most efficient filter operation was obtained at high pressure differential. The precoat efficiency is highest at high pressure differential and Knife advance rates.

Conditions developed for an optimum run based on the test program, to give maximum filtration rate and maximum solids removal efficiency are shown in Table 1-12.

1.2.3.4 Dissolver Operation Studies

Coke Deposits: Periodic inspections of the dissolver indicated presence of coke deposits in the dissolver. In September 1976 it was revealed that nearly 15 ft³ of the bottom section of the dissolver was filled with coke resulting in 35 ft³ of apparent free volume for the half-dissolver operation. Coke deposits contained numerous small flow channels and were not of uniform composition. The coke was removed by hydroblasting. Dissolver temperature profiles showed that coke-free dissolver exhibited a much greater exotherm than

TABLE 1-12

PROPOSED OPTIMUM FILTRATION RUN

Filter Temperature	500°F or higher
Drum Submergence	35% diameter (up to bearings)
Pressure Differential	40 psi or higher
Drum Speed	3-4 rpm
Knife Advance	1 Mil/Rev.
Wash Solvent to Cake	600 lbs/hr
Precoat	Speedplus
Base Coat	Dicalite 6000 (no asbestos)
Slurry Feed	25,000 lbs/hr.

before hydroblasting. Exotherm decreased as coke deposit built up. However, the decrease did not seem related to the amount of coke present. To explain the decreased exotherm it was hypothesized that coke deposits were formed by the gradual build-up of small coke particles which were removed during the shutdown and flushing operation and that the measured S:C ratio was higher than actual ratios as determined in the laboratory.

Temperature Profile: A study of the temperature profile between pre-heater outlet and dissolver outlet indicated that even with three phases present plug flow existed in the transfer line and substantial backmixing in the dissolver.

It was observed that exotherm between heater outlet and dissolver outlet are greater at low flow rate (2700 lbs/hr) than at moderate flow rate (3700 lbs/hr). Also, in the low flow case there was greater exotherm at dissolver inlet. The reasons for this difference are: more sensible heat requirement, decreased liquid residence time and a decreased hydrogen concentration in the moderate flow case. The dissolver inlet area is a very crucial reaction and heat transfer area. Data also indicated that more exothermic hydrogenation occurred in the upper section of the dissolver contributing to the total exotherm.

2. PROCESS ENGINEERING STUDY

Based on the published information on the process conditions developed in the pilot plants, a conceptual design for a 20,000 TPD coal feed SRC-I plant was prepared. In this section a design basis for the commercial plant was developed based on pilot plant data from Wilsonville and Fort Lewis. A process description with block flow diagrams and material balances was developed for the 20,000 TPD plant including hydrogen manufacture and waste treatment systems. A summary of energy balance and thermal efficiency of the plant was developed. A list of raw materials required is included as well as the characteristics of the product. A discussion of the size and delivery of major equipment concludes this section.

2.1 DESIGN BASIS (6.13.12, 6.12.10, 6.12.12, 6.13.13)

In a study sponsored by U.S. ERDA in 1976, TRW carried out a correlation of data from the Fort Lewis and Wilsonville SRC pilot plants. Computer time-sharing programs for calculating the time-temperature reaction severity in the dissolver and preheater-transfer line sections of both pilot plants were developed. This study showed that a good match exists between yields of SRC and most other products for runs with corresponding temperature, residence time and solvent boiling ranges. It was concluded that for scale-up with coal similar to Western Kentucky #9 & 14, data from either pilot plant could be used. Therefore, in this study the data obtained at Wilsonville in Runs 70 through 81, and at Fort Lewis in Runs 4 through 9 using Kentucky #9 & 14 coals and solvent of boiling range 450 to 780°, were used to develop a design basis for a commercial plant design of 20,000 TPD coal feed capacity and are given in Table 2-1.

TABLE 2-1

DESIGN BASIS FOR A 20,000 TPD COAL FEED SRC-I PLANT

1. Coal Type:	Kentucky 9-14 Colonial Mine	
Unground Coal Moisture:	9.2 wt.%	
2. Ground Coal Analysis		
A. Proximate Analysis (Dry basis)	Wt.%	
Volatile Matter	39.8	
Fixed Carbon	49.8	
Ash	10.4	
High Heating Value (MF)		12,760 Btu/lb
Moisture (wt.%)	2.0	
B. Ultimate Analysis (Dry Basis)		
Carbon	70.4	
Hydrogen	5.1	
Nitrogen	1.4	
Chlorine	0.1	
Sulfur	3.4	
Ash	10.4	
Oxygen	9.2	
C. Sulfur Forms		
Pyritic	1.5	
Sulfate	0.2	
Organic	1.7	
3. Operating Conditions		
Coal Conc.% MF	38.4	
Space rate lbs/hr-ft ³ , MF	75.0	
Dissolver Outlet Pressure, psig	1650.0	
Hydrogen Purity, Mol %	87.0	
Hydrogen Partial Pressure, psig		
Preheater Inlet	1450.0	
Dissolver Outlet	870.0	
4. Yields		
Conversion, % MAF coal	91.2	
Hydrogen Consumption, % MF Coal	1.95	
Yields, % MF Coal		
CO	(-0.14)	
CO ₂	0.64	
H ₂ S	1.81	
C ₁	1.40	
C ₂	0.76	
C ₃	0.76	
C ₄	0.16	
C ₅	0.17	

TABLE 2-1 (Cont'd)

4. Yields (Cont'd)

IBP-350°F	2.92
350°F - 450°F	7.58
450°F - EP	2.11
SRC	61.66
Unconverted Carbon	7.86
Ash	10.15
H ₂ O	4.11
Sulfur in SRC, %	0.96

5. Organic Sulfur Removal, % 57.5

6. N₂ and O₂ Removal

	<u>In Feed Coal, Wt. %</u>	<u>In SRC, Wt. %</u>	<u>% Removal</u>
N ₂	1.36	1.72	22
O ₂	9.32	4.44	71

7. Recycle Solvent Boiling Range 450-780°F

8. Filter Cake Composition (Feed to H₂ Plant)

	<u>Wt. %</u>
C	46.38
H	3.36
N	0.90
Cl	0.02
S	6.17
O	4.40
Ash	38.77

9. Physical Properties

A. Sp. Gr. of Various Coal Slurries

Conc. %	25		38	
Temp., °F	60	150	60	150
Sp Gr	1.083	1.065	1.133	1.106

B. Sp. Gr. of Process Solvent (450-780°F)

Temp., °F	60	150	200	250
Sp Gr	1.025	0.980	0.972	0.955

TABLE 2-1 (Cont'd)

9. Physical Properties (Cont'd)

C. Viscosity of Coal Slurries

Conc. %	25			38.5		
Temp. °F	85	125	165	85	125	165
Visc., CP	55	35	21	177	70	62

D. Properties of Liquid Products

Product	Liquid, BP°F	API ⁰	Average BP°F	Average MW	Btu/lb
Light Oil	IBP-350	15.9	320	115	19,000
Wash Solvent	350-450	10.0	400	130	18,000
Process Solvent	450-780	4.6	567	170	17,000
SRC		-22.6	1300	750	15,800

10. Funda Filter Operation

Filtration ΔP , psi	60.0
Dry Cake Loading, lbs/ft ²	6.8
Precoat ΔP , psi	4-14
Cycle Filtration Rate, FPH/ft ²	20
Filtration Temp., °F	550-600
Filtrate Solids, %	0.004
Precoat	Fibra-Flo 7-C
Precoat Loading Rate, lbs/ft ²	0.25

11. Dissolver Flash Stages and Product Recovery Flashes

Calculations were carried out using CHEMSHARE Computer programs for flash calculations using CHEMSHARE library and data for K-values.

TABLE 2-1 (Cont'd)

12. Waste Water Compositions

Source	NH ₃ mg/l	H ₂ S mg/l	Phenol mg/l	Extr. Oil mg/l	BOD mg/l	COD mg/l	T.S.S. mg/l	pH	Flow GPM	Stream No. (FS-9)
SRC Process	5,600	4,000	4,500	200	10,000	15,000	300	8.0	310	71
Process Waste to Biological Treatment Unit	52	Tr	70	20	160	2,000	52	7.4	414	76
H ₂ Plant & Storm Water Run-off	200	0.5	100	100	200	2,000	50	10.5	150	79
Coal Pile Run-off & Treated Effluent	8.0	Tr	0.07	3	15	30	15	7.0 to 9.0	2630	87

2.2 PROCESS DESCRIPTION (6.10.37, 6.11.1 & .2)

In the following pages, a description of the SRC process is given. An overall process flow diagram is shown in Dwg. FS-10, Fig. 2-10. The process is divided into several areas, as listed below. Also listed are the corresponding drawing numbers of the respective block flow diagrams.

	<u>Drawing</u>	<u>Figure</u>
Coal Receiving and Preparation	FS-1	2-1
Slurry Preparation, Preheating and Dissolving	FS-2	2-2
Hydrogen Recovery	FS-3	2-3
Precoating and Filtration	FS-4	2-4
Solvent Recovery	FS-5	2-5
Product Recovery and Solidification	FS-6	2-6
Hydrogen Manufacture	FS-7	2-7
Waste Gas Treatment	FS-8	2-8
Waste Water Treatment	FS-9	2-9

A material balance for each Section is given below the block diagram except for FS-9 and FS-10 where the material balances are given in Tables 2-2 and 2-3, respectively.

2.2.1. Coal Receiving and Preparation (FS-1)

2.2.1.1. Raw Coal Receiving System

For the purpose of this study it was assumed that the coal was delivered to within the battery limits of the plant. Coal was recovered from the coal pile and delivered to bunker hoppers for pulverizing.

2.2.1.2 Raw Coal Preparation System

The coal preparation facilities start at the discharge of the bunker hoppers and include all equipment up to the slurry tank.

Raw coal from the ten double hoppers is fed to 10 pulverizers, eight active and two standby. Each pulverizer is provided with a screw feeder. Coal is pulverized to 90% through 50 mesh and pneumatically conveyed to eight pulverized coal surge bins.

Source of the conveying air is the waste gas from gas-fired combustors which also dries the coal from a total of 9.2% surface and inherent moisture down to 2%[±]. The waste gas is under 10-15" s.p. developed by an air blower.

The pulverized coal is conveyed to the surge bins where a cyclone separator removes the coal while the warm gas is recycled to the combustor after being filtered in a baghouse.

To prevent excess buildup of moisture in the recycled gases, about 15% is bled off to atmosphere. This is replaced by a combination combustion and make-up air. A blower supplements the gases returning to the wind box. Coal accumulated in the baghouse hopper is periodically evacuated by a branch line connecting to the pneumatic transport line to the separator.

Pulverized coal is unloaded from the surge bins by a combination feeder-weigh scale which can be controlled to continuously feed coal to the slurry tanks in the required quantities. A part of the pulverized coal is further ground to 90% through 200 mesh for feed to the Koppers-Totzek gasifier in the hydrogen plant (FS-7).

To prevent possible arching or surface buildup in the surge bin, an active conical hopper is provided each surge bin where free flow is assured either by mechanical agitation or pneumatic aeration of the coal.

A local panel in the slurry tank area permits operator to control and monitor all activities from the raw coal hopper to the slurry tanks.

2.2.2 Slurry Preparation, Preheating and Dissolving (FS-2)

Dry pulverized coal is conveyed to a slurry mix tank where it is mixed with sufficient recycle process solvent. The solvent is cooled before mixing by interchange with the slurry feed and further cooled to 150°F in air cooler.

A slurry recycle pump provides the necessary suction conditions for the slurry feed pump. The coal slurry is pumped through a series of temperature

increasing heat exchanges; first with solvent, second with reacted slurry and vapors, and finally reaching reaction temperature in a slurry preheater. A hydrogen-rich recycle gas is introduced into the slurry just prior to entering the preheater.

The reacted slurry is separated from its vapor. The slurry is cooled to 600°F by exchange with the slurry feed while flowing to a filter feed flash tank (FS-4).

The overhead vapors are condensed and cooled to 110°F in a series of heat exchangers. The condensate and cooled vapor flow by gravity to condensate separator. The first exchange is with the slurry feed. The next exchangers preheat boiler feed water and produce a quantity of 50 psig and 150 psig steam. The next exchange is with the bottoms from condensate separator. The last exchange is with cooling water. This liquid phase flows to solvent recovery (FS-5). The water phase from condensate separator is sent to waste treatment.

2.2.3. Hydrogen Recovery (FS-3)

The hydrogen rich gas phase is scrubbed in an oil absorber to lower the H₂S and CO₂ concentrations. It is then compressed to 2000 psig and introduced into the coal feed slurry as recycle gas. Fresh hydrogen is mixed with the recycle gas to make up what is consumed in the reaction.

The oil absorber uses a light solvent obtained from the overhead of the wash solvent column. The solvent is cooled, then pumped to the top of the absorber. The H₂S rich solvent is flashed into a rich oil flash drum by pressure reduction to 10 psig. The liquid phase is returned to the absorber. The vapor phase is compressed and sent to waste gas treatment. Water accumulated in the flash drum is sent to waste water treatment.

2.2.4. Precoating and Filtration (FS-4)

The reacted coal solution off the dissolver is flashed to 110 psig in a filter feed flash tank. The flashed vapor is fed continuously to a process solvent column (FS-5). The liquid phase is pumped to a filter feed surge tank to await filtration.

Ash removal is accomplished batch-wise in a group of 30 horizontal leaf Funda filters. The filter is precoated with diatomaceous earth as described later. Next a batch of coal solution containing ash and undissolved coal is filtered, the filtrate being sent to product recovery (FS-6). The filter cake is next washed with wash solvent. Next the pressure is reduced to 150 mm Hg abs. using a vacuum jet. This leaves a solvent content of 10% on the filter cake. After breaking vacuum, the filter cake is discharged from the filter into a hopper. From the hopper the cake is metered into a close-loop inert gas conveying system and discharged into a gasifier feed hopper. The filter cake is then charged to a Koppers-Totzek gasifier for hydrogen manufacture.

Precoat solvent and wash solvent makeup are the bottoms product from a wash solvent column. Wash solvent makeup is preheated to 600°F with Therminol.

Precoat material is unloaded pneumatically from rail cars and stored in precoat storage silos. This precoat material is conveyed pneumatically to precoat surge bin, as required. From here it is fed by weigh feeder to precoat slurry tank. A ratio controlled quantity of solvent is added to produce a 7% slurry. This is pumped to the precoat tank and further diluted in precoat circulation tanks. At the beginning of each filtration cycle, the dilute slurry is circulated through the Funda units to apply the precoat.

2.2.5. Solvent Recovery (FS-5)

Solvent bearing streams from the various processing areas are fractionated to recover the solvent. Two columns in series is the necessary arrangement to produce the desired solvent cuts. These are the Process Solvent Column and the Wash Solvent Column.

The feeds to Process Solvent Column are as follows:

1. The high pressure flash condensate from dissolver area (Stream 13) is flashed to 200 psig in a high pressure flash drum. The liquid phase is heated with 50 psig steam and reflashed to 125 psig in an intermediate pressure flash drum. The liquid phase is again flashed to 15 psig in a low pressure flash drum.

Vapors from flash drums are combined and sent to waste gas treatment. Flashed liquid is combined with Stream 30 and fed to the process solvent column.

2. The solvent recovered by vacuum drying the filter cake (Stream No. 22, FS-4) is collected in a Recovered Wash Solvent Surge Tank. This is pumped on flow control to the Process Solvent Column.
3. The flashed vapor from the Filter Feed Flash Tank (Stream 19, FS-4) is combined with the flashed vapor from the Product Recovery (Stream 31, FS-6) and fed directly to the Process Solvent Column.
4. Process Solvent Column reflux is taken off the bottoms of Wash Solvent Column.

Process Solvent Column bottoms is the source of heat for reboiling the Wash Solvent Column bottoms. This solvent is cooled in the Wash Solvent Column Reboiler before being heated in the Process Solvent Column Reboiler. This bottoms product is the process solvent used in preparing the coal slurry.

The overhead vapor from Process Solvent Column is the feed to Wash Solvent Column. This column produces as a bottoms product the solvent used to wash the filter cake. The wash solvent is collected in a Wash Solvent Surge Tank and pumped out as required to the filter wash system. A portion of this wash solvent is used as reflux in Process Solvent Column. Some wash solvent is used as precoat make-up solvent. Excess wash solvent is cooled and sent to sales.

The Wash Solvent Column overhead is condensed in a two-stage condenser; the condensate and cooled vapor going to a Wash Solvent Column Reflux Drum. The first stage generates 25 psig steam; the second stage rejects heat to cooling tower water. The condensate is pumped as reflux to Wash Solvent Column with a portion going to a Light Oil Surge Tank as overhead product. This light oil is used as solvent makeup to the H₂S Oil Absorber (FS-3). excess is pumped to a light solvent storage tank for sale.

The overhead vapor from reflux drums are combined, compressed to 15 psig, and sent to waste gas treatment. Any water accumulated in the drums is sent to waste water treatment.

Three solvent fractions are recovered. The net production of each goes to storage tanks in this area. Thirty days of storage capacity is provided. Pumps are provided for loading the product into tank cars.

2.2.6 Product Recovery and Solidification (FS-6)

Filtered coal solution is collected in an SRC recovery feed tank. This coal solution is heated in an SRC recovery heater and flashed to 10 psig in an SRC recovery 1st stage flash drum. This liquid is pumped to the 2nd stage flash drum and flashed to 25 mm Hg abs. The bottoms, liquid SRC product, are pumped to an SRC surge tank.

The flash drum overheads are fed to the process solvent columns at appropriate locations (Streams 30 and 31).

The non-condensables are cooled and sent to waste gas treatment. (Stream 42)

The vacuum source is a system of three vacuum jets operated by steam, two intercondensers and an aftercondenser. Condensate is collected in the SRC recovery hotwell and pumped to waste water treatment. (Stream 41)

Liquid SRC from the SRC surge tank is pumped to a battery of 30 stainless steel water-cooled belts, 27 active and 3 spare. The pumping system consists of a loop discharge supply header from which a flow control valve at each conveyor uniformly feeds the product onto the belt. A back pressure valve downstream of the last belt maintains a constant pressure in the supply header and the excess flow is returned to the storage tank which is heated to maintain a constant fluid temperature.

A jet spray cooling water system is provided, integral with the stainless steel belt equipment, which sprays cooling water to the underside of the steel belt. To cool the product from about 600°F to 15° above cooling water temperature, about 1 gallon of water per pound of product is required. As the solidified SRC is discharged off the end of the belt, further cooling is effected with a jet mist spray, designed to reduce the temperature of the SRC to ambient and assist

in preventing any agglomeration which may occur. The quantity of the mist spray is limited to that required to effect the cooling by vaporization of the mist without adding moisture content to the SRC.

During the cooling process, hydrocarbon fumes are released. To contain these fumes, as well as vaporized mist, a hood is provided over (most of) the length of the belt, with connections at the top for an exhaust system which carries the exhaust to a water scrubber for cleaning. Scrubber effluent is sent to waste water treatment.

From the end of the belt, the SRC is gathered in chutes and collected on two opposing belt conveyors, then transferred through a hopper to a belt which carries the SRC to a surge bunker having two-hour surge capacity. A bunker conveyor equipped with a tripper uniformly distributes the SRC in 5-hopper bunkers.

The bunker level is enclosed and provided with a cyclone dust collector for removal of the dust in the bunker area as well as the bunker. Dust collected is chuted back into the bunker.

From the bunker outlet, SRC is picked up by a belt conveyor, transferred to the car loading conveyor, and cars are filled directly or bypassed to storage. The car loading conveyor discharges into a double chute hopper. This hopper is located in a transfer house located directly above the cars on the siding. By operating a selective flop gate, SRC is loaded through a chute into the coal cars or diverted to a stocking-out conveyor in the storage yard.

The stocking-out conveyor feeds into a trailer conveyor extending 750 ft., or the entire length of the storage yard. A travelling tripper unloads into the boom conveyor on the stacker. The stacker is mounted on rails and can follow the tripper, uniformly distributing the SRC along a pile on either side of the stacker. Each pile is 40 ft. high, 150 ft. wide and 700 ft. long, representing 180,000 tons or 15 days storage.

In loading the cars, a radio-controlled diesel electric locomotive is provided. As cars are filled, the radio-controlled engine is moved a car length to a pre-set position until the unit train is loaded, or until more cars are available.

If car loading is to be from stockpile, the reclaim bucket of the stacker recovers the SRC from pile, discharges it on the downstream side of the trailer conveyor, transfers the SRC to a reclaim conveyor that unloads into a hopper in the reclaim car loading house also located above the tracks, from which cars are filled in the same manner as described above.

To contain dust dispersal, a chemical jet dust suppression is provided with spray nozzles located at all open discharge or transfer points in the handling system as well as discharge into stockpile.

2.2.7 Hydrogen Manufacture (FS-7)

The hydrogen plant facilities start with 1,260 tons per day of pulverized coal and 4,761 tons per day of dry filter cake from the filtration system of the SRC process. In the coal preparation section the coal is pulverized to 90% minus 50 mesh, dried to 2% moisture content. It is further pulverized to 90% -200 mesh and then mixed with the powdered filter cake. Pneumatic conveying systems are employed for the coal and filter cake transportation; oxygen and steam carry the feed into the Koppers-Totzek gasifiers.

The oxygen, steam and coal react to gasify the carbon and volatile matter of the feed and to convert the coal ash into molten slag. About one-third of the raw coal is completely combusted to provide enough heat for ash slagging at 2700°F. Part of the molten slag drops into a quench tank below the gasifier. The gas exiting gasifier is directly quenched with water to solidify entrained slag droplets. Approximately 50% of the total ash is recovered in the quench tank. Granular quenched slag is conveyed from the quench tank to a dewatering bin for disposal as landfill.

After quenching, the gas and entrained particles of ash and unreacted carbon from the gasifier pass through a waste heat boiler where 700 psig saturated steam is produced. The gas leaves the waste heat boiler at 350°F and passes through a cyclone separator where 90% of entrained solid particles are removed and sent to the quench tank.

The gas from the cyclone separator then passes through a gas clean-up system which is composed of a direct spray type washer-cooler, two Theisen disintegrators connected in series, a mist eliminator, and a wet electrostatic precipitator. A gas blower is provided after the mist eliminator to boost the gas pressure. The gas leaves the precipitator at 15 psia and 98°F with a maximum of 0.0001 grains of particulates per dry SCF, and is sent to the first Selexol unit for H₂S removal.

Water from the precipitator is pumped to the gasifier slag quench tank for slag cooling. Particulate laden waters from the slag quench tank, the washer-cooler, the disintegrators and the mist eliminator are piped to a clarifier. Underflow from the clarifier is pumped to a rotary vacuum filter in which the solids are removed in the form of a filter cake containing 35% water. The filter cake is conveyed to a pit for draining and ultimate disposal as landfill. The filtrate is pumped to the clarifier clearwell.

Allied Chemicals' Selexol process is one of the most efficient acid gas (H₂S and CO₂) removal processes, particularly for the selective removal of H₂S over CO₂. The selectivity of Selexol solvent is known to be superior over other processes using amine or hot potassium carbonate. However, the Selexol process is known to have two major drawbacks. The first one is the high solubility of hydrocarbons in Selexol. The second one is that the selective removal of H₂S over CO₂ is considerably reduced if the accompanying COS in feed gas need be removed completely. This is due to the solubility characteristics of H₂S, CO₂ and COS in Selexol.

The first drawback presents no problem as far as the gas in the H₂ plant is concerned because there is no hydrocarbon present. The second drawback is overcome by the scheme shown in FS-7. In the first Selexol acid gas treatment, prior to shift conversion, no COS is removed, allowing only a minimum amount of CO₂ to pass to the Claus plant. All of the COS present is left in the feed to shift unit. Feed gas stream to the shift unit containing total sulfur less than 4000 ppm can be treated by a sulfur-resisting Co-Mo shift catalyst without any adverse effect on the catalyst. This is the case with COS-bearing gas leaving the first Selexol unit. In the high temperature shift process, all the COS will

be converted to H_2S . From the second Selexol gas treatment following the shift unit, the converted H_2S and some CO_2 are sent to the Claus plant, while most of the CO_2 is vented.

The purified H_2 gas is mixed with recycle H_2 gas and charged to the process.

2.2.8 Waste Gas Treatment (FS-8)

The waste gas treatment system shown in the block flow diagram, FS-8, features:

- Benfield acid gas removal system

- Cryofining and stabilizer units

- Claus plant and SCOT unit

- Off-gas (Not Treated - But Incinerated)

The scheme described above makes it possible to achieve low gas volume to Claus unit with high H_2S concentration, keeping the size of the Claus plant within conventional limits.

2.2.8.1 Benfield Process for Treating Purge Gases

The selective removal of H_2S over CO_2 by the Benfield process is not as good as in the Selexol process, in general. However, the purge and waste gas streams emerging from the SRC plant contain large amounts of hydrocarbons with minor quantity of CO_2 . Since the Benfield solvent dissolves very small amounts of hydrocarbons, it is better suited for application here. The treated gas from the process is then passed to the cryofining unit to recover hydrogen. The off-gases are fed to a Claus unit.

2.2.8.2 Cryofining and Stabilizer Units (for Purge Gases)

Since the gas stream from the Benfield process contains a considerable amount of hydrogen, it is recovered by Air Products and Chemicals' "Cryofining" process. The process consists of an adsorber and a cold box, and recovers hydrogen gas of 86% purity. Recovered hydrogen is recycled back to the SRC plant to minimize the need of fresh hydrogen makeup. Recovered condensate, being very small in quantity, is incinerated.

Tail gas separated in the Cryofining process contains mostly the hydrocarbons of high-heating value. The gas is stabilized to yield fuel gas and LPG. High heating value of the fuel gas is about 1160 Btu/scf.

2.2.8.3 Claus Plant and SCOT Unit

Composition of Streams 51, 56, 58 and 73 to the Claus unit seem to be high in H_2S concentration. Of concern also would be the amount of ammonia present. The first difference should be explainable since the Selexol process employs a series of flash drums to minimize deliberately the amount of CO_2 . Concerning the ammonia content, the ammonia comes from the liquefaction area since the Koppers' gasifier generates negligible amounts. However, the amount of ammonia produced is very small and is not expected to affect the Claus plant operation. A SCOT unit is attached to the Claus plant to achieve a 99.9+% sulfur removal. The vent gases from the SCOT unit are incinerated.

2.2.8.4 Off-Gas (Not Treated - but Incinerated)

Streams 24 and 42, because of their composition (high content of oxygen, inerts and water vapor with negligible light hydrocarbon) flow directly to the combustion zone of an incineration unit.

2.2.9 Waste Water Treatment

The waste water treatment systems for various effluents are schematically shown in FS-9. The compositions of feed streams and effluent streams were developed from criteria developed both at the Fort Lewis and Wilsonville pilot plants, as shown in Item 12, Table 2-1. The treatment of waste water effluents from the SRC plant and H_2 plant are combined for treatment prior to discharge. The treatment of process area run-off and coal pile run-off is also included.

The waste effluents from process plants are first collected in an equalizer tank where stray oil contamination is removed by gravity separation. The waste stream is then treated in a Phenosolvan plant where extractable oils and phenolic material are recovered. Recovered organics are used as plant fuel.

The treated water is then steam-stripped for H_2S removal in an acid stripper. Provision is made for sulfuric acid addition to maintain a low pH.

The acid gas is fed to the Claus plant. The pH of the stripped water is then adjusted with lime addition for the release of combined ammonia and the lime sludge removed in a clarifier. Lime-sweetened water is steam stripped again, this time to remove ammonia. Depending on the amount of ammonium salts present, the ammonia vapors are either sent to the incinerator when the amount is small, or condensed at 25% aqueous solution if it is large. The stripped water is charged to an activated sludge treatment system prior to discharge or reuse.

The storm water run-off from process areas is collected in the run-off pond and then charged to an oil separator. It is then treated in a series of treatment units for cyanide removal by chlorine oxidation, chromium removal by SO_2 and heavy metal precipitation by lime treatment. After desludging, the clarified water is charged to the activated sludge treatment unit.

Coal pile run-off is collected in the run-off pond, treated with lime and alum to settle out solids, clarified, and discharged to the river.

Sludges from various clarifiers which may contain as much as 15% solids are dumped into a lime-sludge dewatering lagoon. The clear overflow is returned to the neutralizer upstream of the activated sludge unit.

NOTE: In this scheme it is assumed that treated water will be discharged to the river. However, in the future it may become necessary to meet "zero discharge" requirements. The process schemes published so far do not include such provisions, perhaps because very little data are published on actual aqueous effluent streams from SRC plants that would make it possible to design for "zero discharge" by specifying and sizing necessary tertiary treatment systems.

2.3 FLOW DIAGRAMS AND MATERIAL BALANCES (6.10.37, 6.11.1 & .2)

Included in this section are Figures 2-1 to 2-8, Block Flow Diagrams of various processing areas described in Section 2.2 and the corresponding material balances. Also included is Fig. 2-9, the block flow diagram of waste water treatment system with material balances as given in Table 2-2.

An overall flow diagram of the plant and material balance are given in Figures 2-10 and Table 2-3, respectively.

FIGURE 2-1
SRC-I PROCESS FS-1
COAL RECEIVING AND PULVERIZING

**Numerals in parentheses are Stream Numbers

MATERIAL BALANCE

Stream No.	1	2	3	4	64	65	
Hydrogen							
CO							
CO ₂							
H ₂ S							
O ₂							
N ₂							
C ₁							
C ₂							
C ₃							
C ₄							
C ₅							
Light Oil							
Wash Solvent							
Process Solvent							
SRC							
Coal	*776.83	45.99	730.83	0.012	115.24	115.23	
Ash	92.52	5.48	87.04	0.001	14.98	14.98	
Precoat							
H ₂ O	88.08	1.05	16.67	70.36	73.02	2.66	
Total	957.43	52.52	834.54	70.373	203.24	132.87	
Temp. OF							
Pressure, PSIG							

* All flow rates are in tons per hour.

FIGURE 2-2
SRC-1 PROCESS FS-2
SLURRY PREP, PREHEATING AND DISSOLVING

**Numerals in parentheses are Stream Numbers

MATERIAL BALANCE

Stream No.	3	5	6	7	8	9	10	11	12	13
Hydrogen				45.82	45.82	27.88	2.03	27.61		0.27
CO				2.99	2.99	1.49	0.37	1.46		0.03
CO ₂				7.93	7.93	11.57	1.60	10.61		0.96
H ₂ S				4.29	4.29	17.45	1.61	12.28		5.17
O ₂										
N ₂				7.08	7.08	3.77	3.31	3.77		
C ₁				30.63	30.63	39.16	2.92	37.41		1.75
C ₂				3.42	3.42	8.82	0.82	7.75		1.07
C ₃				1.23	1.23	6.86	0.59	5.53		1.33
C ₄				0.05	0.05	1.17	0.19	0.46		0.71
C ₅				0.01	0.01	1.17	0.24	0.21		0.96
Light Oil				0.62	0.62	16.16	8.36	0.02		16.14
Wash Solvent						36.96	25.06			36.96
Process Solvent			1306.67		1306.67	528.00	795.93			528.00
SRC							504.26			
Coal	*730.83				730.83		64.27			
Ash	87.04				87.04		83.00			
Precoat										
H ₂ O	16.67	11.47			5.2	33.31	5.48	0.17	33.14	
Total	834.54	11.47	1306.67	104.07	2233.81	733.77	1500.04	107.28	33.14	593.3
Temp. °F		200	500	110	800	825	625	110	110	13
Pressure, PSIG		60	60	2000	1960	1650	1650	1585	1585	158

* All flow rates are in tons per hour.

FIGURE 2 - 3
SRC-1 PROCESS FS-3
H₂ RECOVERY

**Numerals in parentheses are Stream Numbers

MATERIAL BALANCE

Stream No	7	11	14	15	16	17	28	59
Hydrogen	*45.82	27.61	26.44	1.17	16.09			3.29
CO	2.99	1.46	1.34	0.12	1.64			0.01
CO ₂	7.93	10.61	7.47	3.14	0.46			
H ₂ S	4.29	12.28	4.29	7.99				
O ₂								
N ₂	7.08	3.77	3.54	0.23	3.39			0.15
C ₁	30.63	37.41	26.62	10.79				4.01
C ₂	3.42	7.75	3.38	4.37				0.04
C ₃	1.23	5.53	1.23	4.30				
C ₄	0.05	0.46	0.05	0.41				
C ₅	0.01	0.21	0.01	0.20				
Light Oil	0.62	0.02	0.62	2.20			2.8	
Wash Solvent								
Process Solvent								
SRC								
Coal								
Ash								
Precoat								
H ₂ O		0.17				0.17		
Total	104.07	107.28	74.99	34.92	21.58	0.17	2.8	7.5
Temp. °F	110	110	109	119	110	119	150	
Pressure, PSIG	2000	1585	1580	10	2000	10	10	

* All flow rates are in tons per hour.

FIGURE 2 - 4
SRC-1 PROCESS FS-4
PRECOAT AND FILTRATION

MATERIAL BALANCE

Stream No	10	18	19	20	21	22	23	24	25	26	27	68
Hydrogen	*2.03	0.05	1.98	0.05								
CO	0.37	0.02	0.35	0.02								
CO ₂	1.60	0.07	1.53	0.07								
H ₂ S	1.61	0.09	1.52	0.09								
O ₂												
N ₂	3.31	0.05	3.26	0.05								
C ₁	2.92	0.09	2.83	0.09								
C ₂	0.82	0.06	0.76	0.06								
C ₃	0.59	0.05	0.54	0.05								
C ₄	0.19	0.03	0.16	0.03								
C ₅	0.24	0.04	0.20	0.04								
Light Oil	8.36	4.60	3.76	5.31	0.05	0.74			1.45		0.05	
Wash Solvent	25.06	17.36	7.70	36.18	10.87	120.33		0.03	144.65		5.40	
Process Solvent	795.93	713.43	82.50	673.33	4.80	36.65			1.30		0.05	
SRC	504.26	504.26		475.01	29.25							
Coal	64.27	64.27			64.27							
Ash	83.00	83.00			83.00							
Precoat					5.50					5.50		
H ₂ O	5.48	0.96	4.52	0.96			1.68					1.68
Total	1500.04	1388.43	111.61	1191.34	197.74	157.72	1.68	0.03	147.40	5.50	5.50	1.68
Temp. °F	625	613	613	600	500	200	150	150	600	600	615	
Pressure, PSIG	1650	110	110	110		50			110	110	155	

* All flow rates are in tons per hour.

**FIGURE 2-5
SRC-1 PROCESS FS-5
SOLVENT RECOVERY**

MATERIAL BALANCE

Stream No	6	13	19	22	25	27	28	29	30	31	32	33	34	35	36	37	38	39	49
Hydrogen		0.27	1.98					0.27		0.05		2.03		2.03					
CO		0.03	0.35					0.03		0.02		0.37		0.37					
CO ₂		0.96	1.53					0.94		0.07	0.02	1.62		1.62					
H ₂ S		5.17	1.52					4.46		0.02	0.71	2.32		2.32					
O ₂																			
N ₂			3.26							0.05		3.31		3.31					
C ₁		1.75	2.83					1.73		0.09	0.02	2.94		2.94					
C ₂		1.07	0.76					1.00		0.06	0.07	0.89		0.89					
C ₃		1.33	0.54					1.13		0.05	0.20	0.79		0.79					
C ₄		0.71	0.16					0.41		0.03	0.30	0.49		0.49					
C ₅		0.96	0.20					0.33		0.04	0.63	0.87		0.87					
Light Oil		16.14	3.76	0.74	1.45	0.05	2.8	0.12	0.27	4.92	16.02	26.13		1.46		19.45	0.42	0.49	0.02
Wash Solvent		36.96	7.70	120.33	144.65	5.40		0.07	12.41	23.03	36.89	362.63		0.10			162.27	49.90	0.30
Process Solvent	1306.67	528.0	82.5	36.65	1.30	0.05		0.06	107.51	360.77	527.94	10.84	6.9				9.04	0.44	0.01
SRC																			
Coal																			
Ash																			
Precoat																			
H ₂ O			4.52							0.94		5.46		1.52	3.94				
Total	1306.67	593.35	111.60	157.72	147.4	5.5	2.8	10.55	370.19	390.21	582.8	420.69	6.9	18.71	3.94	19.45	171.73	50.81	0.33
Temp. °F	500	137	613	700	600		150	700	788	635	542	410	500	120	120	120	400	440	440
Pressure PSIG	60	1585	110	50	110		10	110	90	10	50	10	60	1		50	10	80	80

FIGURE 2 - 6

SRC-1 PROCESS FS-6
PRODUCT RECOVERY AND SOLIDIFICATION

** Numerals in parentheses are Stream Numbers

MATERIAL BALANCE

Stream No	20	30	31	41	42	43	44	66	69
Hydrogen	*0.05		0.05						
CO	0.02		0.02						
CO ₂	0.07		0.07						
H ₂ S	0.09		0.09						
O ₂									
N ₂	0.05		0.05						
C ₁	0.09		0.09						
C ₂	0.06		0.06						
C ₃	0.05		0.05						
C ₄	0.03		0.03						
C ₅	0.04		0.04						
Light Oil	5.31	0.27	4.92		0.12				
Wash Solvent	36.18	12.41	23.03		0.69	0.05			
Process Solvent	673.33	307.51	360.77		0.05	5.00			
SRC	475.01					475.01			
Coal									
Ash									
Precoat									
H ₂ O	0.96		0.94	17.6	0.36		10.0	10.0	17.94
Total	1191.34	320.19	390.21	17.6	1.22	480.06	10.0	10.0	17.94
Temp. °F	600	288	635	160	160	580			
Pressure, PSIG	110	90	10	0	0	25mm Hg. 485	40		

* All flow rates are in tons per hour.

FIGURE 2 - 7
SRC-1 PROCESS FS-7
H₂ - MANUFACTURE

**Numerals in parentheses are Stream Numbers

MATERIAL BALANCE

Stream No	2	16	21	46	47	48	50	51	52	54	55	56	88	89	90
Hydrogen		16.08					6.43		6.43	16.2	0.11				
CO		1.64					136.9	0.006	136.89	1.652	0.01	0.002			
CO ₂		0.46					84.9	16.09	68.81	292.70	286.40	5.84			
H ₂ S							11.62	11.62		1.32		1.32			
O ₂															
N ₂		1.39					3.39		3.39	3.39					
COS							2.33		2.33						
NH ₃							0.01	0.01							
H ₂ N							0.02	0.02							
Light Oil			0.05												
Wash Solvent			10.87												
Process Solvent			4.80												
SRC			29.25												
Coal	45.99		64.27												
Ash	5.48		83.00												
Precoat			5.5												
H ₂ O/Steam	1.05			46.00			13.04	1.35	0.19	0.93			26.30	11.50	97.82
Slag							122.39								
TOTAL	52.52	21.58	197.74	46.00	110.34	122.39	254.64	29.10	218.04	315.862	286.52	2.16	26.30	11.50	97.82

* All flow rates are in tons per hour.

FIGURE 2 - 8
SRC-1 PROCESS FS-8
WASTE GAS TREATMENT

****Numerals in parentheses are Stream Numbers**

MATERIAL BALANCE

Stream No.	15	24	29	35	42	51	53	56	57	58	59	60	61	62	63	67	73	91	92
Hydrogen	1.12		0.27	2.03					3.46	0.01	3.29	0.17	0.17			0.01			
CO	0.12		0.03	0.37		0.008		0.002	0.52		0.01	0.51	0.51			0.008			
CO ₂	3.14		0.94	1.62		16.09		5.84	0.16	5.54		0.16	0.16			27.47			
H ₂ S	7.99		4.46	2.32		11.62		1.32	0.06	14.71		0.06	0.06			0.02	0.388		
O ₂																			13.16
N ₂	0.23			3.31					0.27	3.27	0.15	0.12	0.12			52.78			49.51
C ₁	10.79		1.73	2.94					15.45	0.01	4.01	11.44	11.24	0.20		0.01			
C ₂	4.37		1.00	0.89					6.23	0.01	0.04	6.21	5.90	0.31		0.01			
C ₃	4.30		1.13	0.79					6.21	0.01		6.21	3.12	3.09		0.01			
C ₄	0.41		0.41	0.49					1.31			1.31		1.31					
Q	0.20		0.33	0.87					1.40			1.40		1.40					
Light Oil	2.20		0.12	1.46	0.12		3.78												
Wash Solvent		6.01	0.07	0.10	0.69		0.17												
Process Solvent			0.06		0.05		0.06												
CDS																			
HN ₃						0.01										0.0535	0.0435		
HCN						0.02										0.02			
H ₂ O				1.52	0.36	1.35			1.52							16.16		1.52	
															26.30				
TOTAL	34.92	0.03	10.55	18.78	1.22	29.10	4.01	7.16	36.61	23.56	7.50	27.59	21.28	6.31	26.30	96.5515	0.351	1.52	62.61

* All flow rates are in tons per hour.

TABLE 2-2
MATERIAL BALANCE - WASTE WATER TREATMENT FS-9

Stream No.	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Ammonia	*0.44		0.014		0.388	0.038	0.043	0.004	0.008	0.012	0.020		0.005	0.001		0.001	0.005
Sulfide	0.312		0.308			Trace	Trace	Trace	Trace		Trace						Trace
Phenolics	0.351	0.281				0.070	0.075	Trace	0.004	0.006	0.010		0.005	Trace		Trace	Trace
BOD		0.78				0.014	0.015	0.007	0.008	0.0120	0.020		0.001	0.001		0.001	0.008
Suspended Solids	0.023					0.005	0.005	0.007	Trace	0.003	0.903		Trace	0.001		0.001	0.008
Water /Steam	78.0			26.664	1.164	103.5	486.3	486.3	37.8	57.5	95.3	287.5	382.8	68.75	102.5	171.25	657.55
COD	1.170					0.207	0.217	0.015	0.076	0.115	0.191		0.010	0.002		0.002	0.017
Extractable Oils	0.016	0.014				0.002			0.004		Trace						0.002
TOTAL	81.092	0.295	0.322	26.664	1.552	103.836	486.655	486.333	37.900	57.648	95.544	287.5	382.821	68.755	102.5	171.255	657.590

* All flow rates are in Tons Per hour.

FIGURE 2 - 10
OVERALL FLOW DIAGRAM FS - 10
20,000 TPD COAL (KY. 9 & 14) FEED SRC -1 PROCESS

TABLE NO. 2-3

OVERALL MATERIAL BALANCE (REF. FS-10)
(All flow rates are in tons per hour.)

Stream No	1	2	3	4	5 & 12	6	7	10	11	14	15	16	17	19	20	21	22	23	24	25	26	27	28	29 & 35
Hydrogen							45.812	2.03	27.51	26.44	1.17	16.09		1.98	0.05									2.30
CO							2.99	0.37	1.46	1.34	0.12	1.64		0.15	0.02									0.40
CO2							7.93	1.60	10.61	7.47	3.14	0.46		1.53	0.07									2.56
H2S							4.29	1.61	12.28	4.29	7.99			1.52	0.09									6.78
O2																			0.0					
N2							7.08	3.31	3.77	3.54	0.23	3.39		3.26	0.05				0.0					3.31
C1							30.63	2.92	37.41	28.62	10.79			2.83	0.09									4.67
C2							3.42	0.82	7.75	3.38	4.37			0.26	0.06									1.89
C3							1.23	0.59	5.53	1.23	4.30			0.54	0.05									1.92
C4							0.05	0.19	0.46	0.71	0.05	0.41		0.16	0.03									0.90
C5							0.01	0.24	0.21	0.96	0.01	0.20		0.20	0.04									1.20
Light Oil							0.62	8.36	0.02	0.62	2.20			1.76	5.31	0.05	0.74			1.46		0.05	2.8	0.17
Wash Solvent								25.06		15.94				2.70	36.18	10.87	120.33		0.03	144.65		5.40		0.06
Process Solvent						1306.67		795.93		56.96				82.50	673.33	4.82	36.65			1.3		0.05		
SRC								504.26							475.01	29.25								
Coal	776.83	45.99	730.83	0.312				64.27								64.27								
Ash/Slag	92.52	5.48	87.04	0.301				83.00								83.00								
Precoat																5.5					5.5			
H2O	88.08	1.05	16.67	70.36	44.61			5.48	0.17				0.17	4.52	0.96			1.68						1.52
CO2																								
Ammonia																								
H2S																								
Sulfur																								

Stream No	30 & 31	34	36	37	39	41 & 45	42	43	46	47	48	49	51 & 56	53	55	59	61	62	63	64	73	87		
Hydrogen	0.05														0.11	3.29	0.17							
CO	0.02												0.008		0.01	0.01	0.51							
CO ₂	0.07												21.93		286.4		0.16							
H ₂ S	0.09												12.94				0.06				0.308			
O ₂																								
N ₂	0.05															0.15	0.12							
C ₁	0.09															4.01	11.24	0.20						
C ₂	0.06															0.09	5.90	0.31						
C ₃	0.05																3.12	3.09						
C ₄	0.03																	1.31						
C ₅	0.04																	1.40						
Light Oil	5.19			19.45	0.49		0.12					0.01		3.78										
Wash Solvent	15.44				49.9		0.69	0.05				0.31		0.08										
Process Solvent	668.28	6.9			0.44		0.05	5.00				0.01		0.06										
SRC								475.01																
Coal																								
Ash/Slag											122.39									115.24				
Precoat																				14.98				
H ₂ O/Steam	0.94		3.99			27.6	0.36		46.03				1.35							73.02		657.55		
CO ₂																								
Ammonia													0.01								0.014	0.005		
H ₂ S													0.02									Trace		
Sulfur																				26.30		Trace		
Phenolics																						0.008		
BOD																						0.008		
TSS																						0.017		
COD																								
TOTAL	711.13	6.9	3.99	19.45	50.41	27.6	1.22	480.06	46.03	10.34	122.39	0.33	36.26	3.92	286.52	7.50	21.28	6.31	26.30	203.24	0.122	657.588		

2.4 ENERGY BALANCE AND THERMAL EFFICIENCY. (6.10.37, 6.11.1 to .3)

An overall energy balance for the SRC plant was developed using coal feed as the input. It was assumed that this plant was self-sufficient in process fuel by using SNG, LPG and some oils produced in the plant as fuel. This also eliminated any need for flue gas treatment system which would be required with purchased fuel. It was also assumed that electric power would be purchased.

The product slate includes SRC, medium oil and process solvent as product fuel gases, light oils and some medium oil are consumed as plant fuel. Sulfur is the only by product. Some phenolics recovered in the waste water treatment system are burned as fuel. However, no credit for any of these items is included in the energy balance.

A summary of the energy balance is given in Table 2-4. It may be noted that input energy is 531.5×10^9 Btu/day which includes coal fed to the SRC process, as well as hydrogen manufacture. Fuel required for various fired heaters is 43.8×10^9 Btu/day. Saleable products, SRC and various solvent fractions account for 413.6×10^9 Btu/day.

Total power required by the plant is 269,630 HP, of which 55,560 HP is provided by by-product steam. The remaining electric power, 214,070 HP, is purchased. This is equivalent to 38.3×10^9 Btu/day, assuming 1 Kw = 10,000 Btu. Energy efficiency is estimated two ways. A direct ratio of saleable product to total coal feed gives a plant thermal efficiency of 78%. It assumes that the purchased power will be regarded as an operating cost rather than an energy expense. If, on the other hand, energy equivalent of power consumed was to be regarded as part of the total plant energy input, the ratio of saleable product to total energy input gives a plant thermal efficiency of 73%.

A diagram of overall energy balance, principal raw materials and products of the plant is given in Fig. 2-11.

ENERGY BALANCE AND THERMAL EFFICIENCY

<u>Coal Feed</u>	<u>Tons/Day</u>	<u>Btu/Day x 10⁻⁹</u>
Process	20,000	500.00
H ₂ -Mfg	<u>1,260</u>	<u>31.5</u>
TOTAL	21,260	531.5

Saleable Products

SRC	11,521	364.1
Medium Oil	1,220	43.9
Process Solvent	<u>166</u>	<u>5.6</u>
		413.6

Energy Consumed as Power @
10,000 Btu/Kwh

214,070 HP Equiv. 38.30

Miscellaneous Products (No Credit)

Sulfur 624

Plant Thermal Efficiency.

A. Without Power $(413.6 \div 531.5) = 78\%$

B. With Power $413.6 \div (531.5 + 38.3) = 73\%$

FIGURE 2 – 11
OVERALL ENERGY BALANCE, PRINCIPAL
RAW MATERIALS AND PRODUCTS
20,000 TPD COAL FEED SRC PLANT

THERMAL EFFICIENCY: WITH POWER 73%
 WITH POWER AS OPERATING COST 78%

2.5 RAW MATERIALS REQUIRED AND LIMITATIONS (6.10.37, 6.11.3)

The following raw materials and chemicals are required for the plant:

Raw Coal (10% Moisture) (Includes 1360 TPD for H ₂ Mfg)	23,000 TPD
Diatomaceous Earth	132 TPD
John-Marsh M-R Compound (Anti-dust Spray)	128 GPD
Lime (95% CaO)	27 TPD
H ₂ SO ₄ (98%)	5 TPD
NaOCl	1 TPD
SO ₂ (Liquid)	0.5 TPD
Claus Plant Catalyst	0.5 TPD (Daily Average Based on 156 Tons/y.)

Other miscellaneous raw materials required are Selexol solvent, carbonate solution, NaOH solution and waste water treatment chemicals. Major raw materials as far as the plant operation is concerned are coal and the precoat material. The effect of various coals on plant operation were examined in Section 1.2. It was observed that most bituminous coals behaved similarly and no significant changes in process conditions were required to achieve the same degree of conversion or product slate. Sub-bituminous coals require higher severity and greater hydrogen consumption as compared to bituminous coals. It has been recognized that moisture has some effect on coal dissolution in that excessive moisture would require intensive drying which tends to oxidize the coal surface and render the coal difficult to dissolve. Such experiences have been reported specifically with Australian Brown coals. Effects of ash on the reaction rates in the dissolver are known to exist, but quantitative information is not available. Inasmuch as organic sulfur is difficult to remove, it is desirable to have as low an organic sulfur content as possible.

Diatomaceous earth is plentiful and new mines will have to be opened to supply the needs of SRC plants. However, this assumes that precoat filters will remain as the preferred method of solids separation. Several promising techniques of solids separation are on the horizon and the availability or the effectiveness of precoat materials may not be a cause of concern for long if any of these techniques prove successful.

2.6 PRODUCT CHARACTERISTICS (6.5.2 to .5, 6.5.8 & .9)

Even though SRC-I is a multi-product process in that it produces several liquid and gaseous products in addition to SRC, for this discussion SRC is regarded as the main product. Normally, SRC is considered a solid fuel, but because of its low melting point it can also be potentially used as a liquid fuel. Data on physical properties of SRC as a solid, as well as a liquid fuel were collected. Also reported here are some of the observations on grindability and combustion characteristics of SRC. Recently a full-scale burn test of SRC was carried out at Plant Mitchell of Southern Services Co. located at Albany, Georgia. Some of the results of this test, especially those concerning the environmental aspect, are also listed.

2.6.1 Properties of SRC as a Fuel

In Table 2-5 are listed the proximate and ultimate analyses, sulfur forms, densities, Hardgrove Grindability Index, melting point, etc. for SRC as solid fuel. Properties of SRC as a liquid fuel listed are specific gravity, pour point, flash point, fire point, Conradson Residue, specific heat, viscosity, etc.

Tests were made on SRC to evaluate solid SRC as a substitute boiler fuel. The following conclusions were drawn from these tests:

1. The SRC has a high Hardgrove Grindability Index indicating ease of grinding. However, the formation of hard agglomerates, observed during the test grinding in the Hardgrove mill, suggests that difficulties may be encountered during full-scale pulverization in ball-and-race mills.
2. Sintering of the SRC can occur as a result of its exposure to excessive temperatures. In the pulverization, transport and storage of the SRC, temperatures should be maintained below 200°F.
3. ASTM fuel analysis reveals that the SRC contains little ash (~0.1%) and sulfur (~0.9%), a high quantity of volatile matter (~60%) and has a high heating value (~15800 Btu/lb. MAF) and hence should be a premium fuel.

TABLE 2-5

PROPERTIES OF SRC AS A BOILER FUEL

I. Solid Fuel Analyses

A. Proximate Analysis

	Wt % (Dry)
Volatile Matter	61.4 - 66.7
Fixed Carbon	33.3 - 38.5
Ash	0.08 - 0.12

B. Ultimate Analysis

Carbon	87.1 - 87.7
Hydrogen	5.5 - 5.9
Nitrogen	1.8 - 2.0
Sulfur	0.7 - 0.9
Ash	0.08 - 0.12
Oxygen (by diff.)	3.98 - 4.22

C. Heating Value (Dry) 15770-15810 BTU/lb

D. Hardgrove Grindability

<u>Temp^oF</u>	<u>Hardgrove Index</u>
10	170-178
70	184-188
150	180-187

E. Sulfur Forms

	Wt % Dry
Pyrite	0.014 - 0.019
Sulfate	0.002 - 0.004
Organic (by diff)	0.684 - 0.877
Total	0.700 - 0.900

F. Melting Point (Hot Stage Microscope), ^oF 284 - 293

TABLE 2-5 (Cont'd)

G. Density

	<u>Bulk Density</u> <u>gm/cm³</u>	<u>True Density</u> <u>gm/cm³</u>
At Sandvik Belt	0.53	
In Storage	0.61	
Cast SRC in Rail car	0.90	
High Ash SRC		1.36
Low Ash SRC		1.24

II. Liquid Fuel Analysis

SP. GR. (450°F/60°F)	0.985 - 1.005	
Pour Point, °F	350 - 355	
Flash Point, °F (ASTM D-92)	360	
Fire Point, °F	520	
Conradson Residue, %	53.1 - 56.5	
Viscosity CP	Temp, °F	CP
	448	622 - 672
	464	273 - 347
	508	72.5 - 96.8
	543	39.5 - 40.1

SP. Ht	Temp, °F	SP Ht $\frac{\text{BTU}}{\text{lb, °F}}$
	100	0.319
	250	0.429
	400	0.494
	550	0.527
	700	0.557

$$C_p = 0.4105 + 2.100 \times 10^{-4} T \text{ (300-700°F)}$$

4. The nitrogen content of the SRC is relatively high. This is likely to result in high nitrogen oxide emissions during its combustion.
5. The Burning Profile Test indicates that in full-scale combustion the SRC ignition should be similar to that of a high volatile bituminous coal and burnout should be similar to that of a low volatile bituminous coal or an easier burning anthracite.
6. For the SRC used as a liquid fuel, the viscosity characteristics indicate that heating to at least 410°F is required for pumping and 540 to 580°F for atomization.
7. The SRC, stored in air as a liquid has a tendency to oxidize and as a result, increase in viscosity. Blanketing the liquid with an inert gas would be required.
8. When fired as a liquid in the same manner as a No. 6 fuel oil, the SRC's high Conradson Carbon Residue predicts high unburned combustibles. This can probably be overcome by modifying burner design.

It was observed that these conclusions were related to the specific SRC studied. Other samples of SRC derived from different coals may exhibit different chemical and physical characteristics.

2.6.2 SRC Burn Test

SRC manufactured at the Fort Lewis SRC pilot plant was shipped to Plant Mitchell in Albany, Georgia for a burn test on a 22.5 MW coal-fired utility boiler. A total of 3000 tons of SRC was used.

SRC was shipped in standard open coal cars. To minimize the losses due to blowing, the cars were sprayed with a liquid latex top coat. To control dust in the conveyor systems during loading and unloading, a wetting agent spray was used. This was necessary as SRC breaks up during handling.

SRC was stored outside on a piece of reinforced plastic and no product degradation occurred during a year-long storage. SRC was conveyed and stored

at the plant in conventional power plant equipment without any equipment modifications. SRC was pulverized in standard equipment except that cold primary air was used and ball spring pressure was reduced from 1150 lb/ball to 500 lb/ball. No loss in pulverizer capacity based on coal grinding was observed. The fineness of SRC exceeded 90% passing 200 mesh due to high Hardgrove Index.

Only boiler modification required was to use specially designed water-cooled burners. Boiler emission tests showed that burning of SRC easily met SO₂, NO_x, CO, CO₂, O₂ and opacity standards set by EPA. There was a problem with particulate loading because the precipitator at Plant Mitchell was old (circa 1946). This was aggravated by the high carbon content of the SRC ash, which made the ash resistivity very low. Tests with a secondary precipitator of modern design, however, showed that EPA compliance can easily be met.

Boiler efficiency tests indicated that efficiency when burning SRC was essentially the same as when burning coal. SRC was shown to be an exceptional boiler fuel from an operating standpoint. Soot-blowers were not used at all during the 18-day test. Normally, soot blowing was done 6-12 times a day at the Mitchell Plant when burning coal. The quantity of flyash generated was 7-10 times less than when firing coal. Bottom ash was virtually non-existent.

2.7 DISCUSSION ON MAJOR EQUIPMENT, SIZE AND DELIVERY

One of the major concerns in the SRC-I plant design is the state-of-the-art of several critical pieces of equipment. Because of the size of the plant and the severity of process conditions, equipment designed for extreme conditions is required. This need affects the availability of the equipment in terms of special features, size, materials of construction, delivery schedule, etc. and the overall plant costs and schedules. Some of this equipment is:

- 1) Coal Slurry Feed Pumps
- 2) Slurry Preheater
- 3) Dissolver
- 4) Filters
- 5) Product solidification units
- 6) Mineral residue gasifier for hydrogen manufacture

A discussion on the selection, size and delivery follows.

2.7.1 Coal Slurry Feed Pumps (6.7.11, 6.7.15, 6.10.37)

There are several applications of slurry pumps encountered in the SRC-I plant. They are:

- Slurry Recycle
- Slurry Feed
- Filter Feed
- Filtrate Feed
- Filter Bottoms
- Product Transfer

Operating temperatures for these pumps vary from 250 to 750°F and solids content would range from 2% to 50%.

The most extreme conditions are encountered in the design of the high pressure slurry feed pump. These feed pumps are reciprocating plunger pumps. These pumps are designed for 2800 psig pressure and 150-350°F temperature. Solids concentrations of 40% should be handled. Both at Fort Lewis and Wilsonville, horizontal single-acting triplex plunger pumps are used. The plunger moves through a wall of clean carrier fluid that isolates the packing from abrasive slurry. Valves of these pumps operate in the slurry and wear out

first. Clusters of ball valves are, therefore, used which turn with each opening and offer new sealing surface to the seat. Valves are made of hardened steel and the seats of tungsten carbide. Pumps and plungers are made of steel.

The problem with these pumps is the size limitation. Total horsepower required for a 20,000 TPD plant approaches 32,000 HP. The size of the largest pumps now available is in the 800-900 GPM or 3000 HP category. Thus, in a 20,000 TPD plant, 10 to 11 pumps would be required and would also necessitate the use of as many slurry preheater coils. An alternate design is a multi-stage centrifugal pump; however, development of such a pump will require extensive research and development effort.

The other applications of slurry handling require hot process slurry pumps. At the present time there are hot centrifugal process pumps available for refineries which can deliver against high heads. There are centrifugal slurry pumps available but they do not develop high heads. Also, due to erosion and abrasion they do not have the safety features needed; nor do they have long service life necessary to assure continuous operation. Therefore, reciprocating pumps have to be used. However, here again there is a size limitation.

2.7.2 Slurry Preheater (6.7.10, 6.7.11, 6.10.37)

Slurry preheater for the SRC-I process has the function of heating a three-phase mixture of coal, solvent and hydrogen-rich gas to a temperature of 800°F under high pressures. Coal concentration in the slurry can be as high as 38%. This presents problems of coking of the tube, unusual temperature/viscosity behavior of coal slurries and erosion of tubes.

A recommended design would be a convective design. This makes for a compact design and offers a high degree of accuracy in estimating outside heat transfer since the tube-side coefficients can only be extrapolated from actual operations. The tubes are placed in a horizontal position for uniform heating. The tubes are connected by diagonal return bends to maintain coal particles in suspension and uniformity of flow. A well-dispersed phase flow is essential to maintain an adequate inside film heat transfer coefficient that prevents coking.

The design velocities at both the Fort Lewis and Wilsonville plants are low. A mass velocity of $500 \text{ lbs/sec} \times \text{ft}^2$ is recommended to insure coal slurry integrity. Even though essential for good inside heat transfer coefficient, the velocity may have to be modified to allow for pressure drop and erosion considerations.

Based on experience at the Cresap and Louisiana, Mo. plants, a heat transfer flux of $12,500 \text{ Btu/hr} \times \text{ft}^2$ is suggested.

At Wilsonville a coil made of SS 316 is used. The Fort Lewis unit is equipped with Incoloy coil. So far at Wilsonville, no appreciable metal loss is observed due to corrosion or erosion. Periodically it is required to be decoked.

For a 20,000 TPD plant the total heat input required for slurry preheating is $880 \times 10^6 \text{ Btu/hr}$. R. M. Parsons in their design specified several fired heaters, each rated for $147 \times 10^6 \text{ Btu/hr}$ duty, which is considered normal size at the present time. However, Southern Company Services study included two units, each rated for $440 \times 10^6 \text{ Btu/hr}$. This higher rating gives fewer units but design of such units needs to be developed. Good pressure drop calculation methods are not available for three-phase flow. Also, in order to assure proper heat flux, optimum tube size should be established. Tubes of diameters larger than 8" may not be economical at high pressures, temperatures and heat flux. A compromise between pressure drop and acceptable velocities from erosion and heat transfer points of view must be realized.

2.7.3 Dissolver (6.7.11, 6.10.37)

For a 20,000 TPD plant, four dissolvers 8 feet in diameter and 106 feet high are prescribed in the Southern Company Services study. Materials of construction would be SA 387 Gr. 22 Class 2 steel with 3/16" thick weld overlay of 347 SS. Shell thickness would be about 6" and head thickness about 3". Weight of each vessel will be about 1,153,000 lbs. Fabrication can be single layer or multi-layer. Struthers-Wells is the only fabricator who prefers multi-layer construction. Nooter, Wyatt and CB&I have facilities to roll 6" thick sheets.

There do not appear to be problems with fabrication, per se. However, deliveries are expected to be very long. It may be interesting to note that Mitsui and Kobe Steel of Japan have quoted prices for these units nearly 50% below the American vendors. (R. M. Parsons specified 10 foot diameter x 69 foot high units.)

At Wilsonville, the dissolver is fabricated from centrifugally cast SS 304 with nozzles and flanges made with SS 347. At Fort Lewis, the dissolvers are lined with a first pass overlay of 390L SS and second pass overlay of 347 SS on SA-336-F22 base. Inspection reports from Fort Lewis indicate that corrosion has caused cracks in welds at nozzles. Localized attack of approximately 0.03 inches deep was revealed in several areas. However, at Wilsonville no cracks were observed. Corrosion and erosion tests are in progress at both pilot plants in the dissolver area.

2.7.4 Filters (6.3.5, 6.10.26A, 6.10.37, 6.13.13)

The Wilsonville pilot plant has been successful with Funda horizontal leaf precoat filters in that ash removal to meet SRC specifications can be achieved; however, it is a batch unit. At present, commercial Funda units with 1100 sq. ft. filter surface are designed. The manufacturer claims that units with 3300 sq. ft. and 5500 sq. ft. surface area are possible. The 20,000 TPD plant design calls for 30 units with 5500 sq. ft. filter area each. This multiplicity of units, plus the need to develop a design for a 5500 sq.ft. unit, puts this filter in a critical category.

The Fort Lewis pilot plant is equipped with two Goslin-Birmingham continuous pressure rotary drum filters. Several difficulties were encountered in the operation of these units. However, after modifications and changes these units were found to be capable of achieving a high clarity in the filtrate.

In a November 1975 study comparing various solid-liquid separation techniques in coal liquefaction processes, it was shown that a 500 sq.ft. Goslin-Birmingham rotary precoat filter and an 1100 sq.ft. Funda filter would be competitive in terms of cost per barrel of product in a 1-million barrel per year plant if the precoat requirements for Funda were reduced below 0.16 lbs. precoat per lb. of ash. It was also shown that the capital requirements for

Funda units would be nearly half that of the Goslin-Birmingham units. In the intervening two years not only the filtration rates and operating efficiency of the Funda have been improved at pilot plant level in Wilsonville, but also the body feed of filter aid has been eliminated and total precoat usage reduced to a level below the projected economic threshold. The manufacturer also claims that larger than 1100 sq. ft. units, i.e., 3300 sq.ft. and 5500 sq.ft. units are feasible. A 3300 sq.ft. unit is on the drawing board. One can, therefore, assume that there will be further benefits in cost accrued due to the increase in size. It, therefore, appears reasonable to assume that the Funda filter, in spite of being a batch unit, is the more economical unit of the two.

Drying of the filter cake and loss of solvent in the cake has plagued the operation at both Fort Lewis and Wilsonville. The current practice at Wilsonville of drying the cake on the filter nest has perhaps eliminated a major bottleneck in filter cake disposal. It eliminates the need of a separate dryer installation with marginal lowering in filter capacity resulting from a slight increase in total cycle time. Economic benefits of the combining filtration and drying have not yet been evaluated. However, the feasibility has been demonstrated. Admittedly, precoat filtration is not the best solution to the problem -- it is the one that is viable at the moment. Of the two alternatives, the Funda unit offers a greater potential of reliable and economic operation. It was, therefore, selected for the plant scheme included in this report.

2.7.5 Product Solidification Units (6.10.37, 6.12.12, 6.13.13)

SRC product solidification at Wilsonville is accomplished by means of Rexnord vibrating trays and at Fort Lewis by Sandvik belts. Both these methods require a large number of units. Also vapors are given off during solidification which need to be collected and disposed of. Alternative methods for solidification under controlled environment should be investigated.

2.7.6 Mineral Residue Gasifier for H₂ Manufacture (6.4.10, 6.10.37)

2.7.6.1 Selection of Koppers-Totzek Gasifier

The SRC-I process scheme presented in this study includes manufacture of hydrogen by gasification of filter cake and coal. The gasifier selected is th

four-headed Koppers-Totzek unit. As yet, there has been no demonstration performed on the K-T unit to gasify the SRC filter cake. Residues from H-Coal process using Illinois 6 and Wyodak coals have been tested recently in a Texaco gasifier. No additional coal was mixed with the residue. Gasification tests were successful and the results were comparable to the gasification of petroleum residue. However, the K-T unit was selected for this study because of the nature of the SRC residue and the many advantages of the K-T unit.

The SRC residue obtained by vacuum drying the filter cake on the Funda filter nest is a free-flowing material even though it contains some solvent and SRC. The particle size of the residue is in the range of 1 to 50 microns. This can easily be combined with pulverized coal (90% -200 mesh) and fed to a K-T unit. On the other hand, it would be necessary to pelletize the residue if it is to be fed to a Texaco gasifier.

A multi-head K-T unit operating at nearly 3300°F results in a nearly 100% conversion of coal irrespective of the rank of coal and generates no undesirable by-products like soot or tar as in the Texaco unit. Texaco units are operated at pressures of at least 24 atmospheres. K-T units operate at pressures slightly above atmosphere.

For a 20,000 TPD SRC plant 183 MM SCFD of Syn-gas (equivalent to 147 MM SCFD Hydrogen) can be produced in 3.3 K-T units, each generating about 56 MM SCFD Syn-gas. Thus, four units would be adequate. Koppers, in personal contacts, have indicated that their gasifier can operate at full capacity and no spare units are necessary. The high ash content of the feed (filter cake and coal) may tend to reduce the capacity of the gasifier. Koppers people say that they can overcome this restriction by increasing the screw feeder diameter from 8" to 10". This would require some short term developmental work. The capacity of a conceptual commercial residue gasifier proposed by Texaco is 75 MM SCFD of Syn-Gas. However, units of this size are yet to be developed.

Large size K-T gasifiers using pulverized coal feed are commercial now. Also, in Europe a K-T gasifier operating at 500 psig is under development.

However, there is no commercial Texaco unit in operation using coal feed. Two units are under construction. Therefore, the atmospheric K-T unit was selected for this study. Some needed development work for the K-T unit includes tests with filter cake as a feed and development of a 10" screw feeder. When high pressure units become commercial it would become an additional factor in favor of K-T units.

2.7.6.2 Advantages and Disadvantages of Char Gasification

There are three key factors governing the use or disposal of the filter cake from the SRC plant. These are thermal efficiency, overall process economics and environmental regulation concerning waste disposal.

If the filter cake is not utilized, additional coal will be required for hydrogen manufacture and the thermal efficiency of the overall process would decrease. Gasification of the raw coal using a K-T gasifier is a proven process; however, gasification of high ash filter cake has yet to be demonstrated. Disposal of filter cake without further processing, such as gasification or combustion, could be of environmental concern. Detailed process economics of alternate hydrogen generation and char utilization schemes have not been evaluated on a comparative basis. This subject is to be further investigated.

3. PROCESS ECONOMICS

3.1 CAPITAL REQUIREMENTS

Detailed economic data pertaining to commercial-sized SRC plants and derived from independent, reliable cost engineering sources are limited. They differ considerably in design criteria, product slate and product quality. It is the purpose of this economic analysis to put a number of these commercial scale SRC cost models on equal footing and then to attempt to explain where and why major variations occur. No attempt is made herein to evaluate the relative accuracy of these models.

Five cost models were used in this economic comparison. Capital costs are broken out by process sections and then analyzed in all but one of these models. The fifth model was stated as a lump sum with no breakdown of costs. The four detailed models include: (1) a study completed by the Process Evaluation Group of the U.S. Bureau of Mines in March 1976 for a 50,000 BPD liquid fuels facility using Illinois #6 coal; (2) a preliminary design and economic analysis prepared by Ralph M. Parsons Company for the U.S. Office of Coal Research in December 1973 for a 25,000 BPD liquid fuels facility; (3) an economic analysis performed by Southern Company Services, Inc. in November 1976 (updated in 1977) for a 20,000 TPD raw coal input facility which produces 10,400 TPD solid SRC product; and (4) an August 1977 recycle SRC processing study conducted by Gulf Mineral Resources Co. which includes a 30,000 TPD SRC unit producing 15,370 TPD solid SRC product. The fifth model is stated as a lump sum for a 50,000 BPD facility using Illinois #6 coal from an article by Sidney Katell, formerly associated with the Bureau of Mines and currently teaching at West Virginia University's College of Mineral and Energy Resources. The Bureau of Mines study is based upon the process used in the Parsons' model, but because the Bureau of Mines does possess its own cost engineering staff, the U.S.B.M. study will be considered as independently derived in this analysis. Sidney Katell's work may also be related to the U.S.B.M.'s study but will be considered unrelated here.

Table 3-1 illustrates the comparative capital cost for each process section of the U.S. Bureau of Mines, Parsons, Southern Services, and Gulf Mineral plants. All four plants have been scaled to process 20,000 TPD of dry coal (not

Table 3-1
COMPARATIVE ECONOMICS
U.S.B.M./Parsons/Southern Company/Gulf Mineral
Capital Costs - Mid-1976, 20,000 TPD

U. S. B. M.	Parsons - 1974	Southern Company	Gulf Mineral Resources SRC-1
\$ Million	\$ Million	\$ Million	\$ Million
Coal Preparation 15.4	Coal Preparation 11.6	Coal Preparation 30.8	Coal Preparation 64.7
Coal Slurrying Pumping 1.5 Coal Liquefaction 143.8 Dissolver Acid Gas Rem. 55.0 Sub-total 200.3	Coal Slurrying Pumping 1.6 Coal Liquefaction 161.3 Dissolver Acid Gas Rem. 38.8 Sub-total 201.7	Coal Slurrying Dissolving Benfield Cryofining Oil Absorption Sub-total 156.5	Hydrogenation Hydrogen Recycle Sub-total 158.1
Filtration 7.6	Filtration 8.5	Filtration 122.3	Filtration 137.3
Product Distillation 8.1 Fuel Oil Hydrogen 60.5 Naptha Hydrogen 5.3 Acid Gas Removal 20.8 94.7	Product Distillation 4.6 Fuel Oil Hydrog. 39.9 Naphtha Hydrog. 4.0 Acid Gas Removal 11.1 Sub-total 59.6	Solvent Degassing and Recovery 50.3	Fractionation 19.2 Product Solidif. 20.0 Sub-total 39.2
Gasification 19.1 Oxygen Plant 25.0	Gasification 32.8 Oxygen Plant 46.3	K-T Gas Producer 73.3 Air Separation 28.9	Gasifier Hydrogen Plant 245.1
Fuel Gas Sulfur Removal 4.4 Shift Converter 16.5 CO ₂ Removal 9.8 Methanation 0.8 31.5	Fuel Gas Sulfur Rem. 3.8 Shift Converter 10.5 CO ₂ Removal 4.8 Methanation 0.8 Sub-total 19.9	Acid Gas Rem. 22.7 Shift and Purification 19.1 Sub-total 41.8	Gas and Secondary Recovery Sub-total 49.7

TABLE 3-1 (Cont'd)

U. S. B. M.	Parsons	Southern Company	Gulf Mineral Resources - SRC-1
Sulfur Recovery \$ Million 4.2	Sulfur Recovery \$ Million 15.2	Claus & Scot \$ Million 14.0	Sulfur Recovery \$ Million 15.0
Waste Water Cleanup 3.5	Waste Water Cleanup 3.0	Waste Water Treatment (NH ₃ , H ₂ S, Phenol) Recovery 13.0	(Incl. Utilities) -
Product Storage 16.0	Product Storage 17.5	Solvent Storage & Shipping 7.2	(Incl. General Facilities) -
Power Plt. 48.9 Plt. Utilities 50.1 Gen. Facilities 35.0 Sub-total 134.0	Power Plant 81.7 Plt. Utilities 32.9 Gen. Facilities 7.4 Sub-total 122.0	Utilities Sys & Offsites 22.4	Utilities 79.0 General Facilities 61.5 Sub-total 140.5
Plant Facility 551.3	Plant Facility 538.1	Plant Facility 560.5	Plant Facilities 849.6
Initial Catalyst and Chemicals 2.7 Interest during Constr. 99.2 Paid-up Royalties 2.7 Start-up Costs 42.8 Working Capital 23.0	Initial Catalyst and Chemicals 2.0 Interest during Constr. 96.9 Paid-up Royalties 2.7 Start-up Costs 42.8 Working Capital 23.0	Initial Catalyst and Chemicals 2.0 Interest during Constr. 101.1 Paid-up Royalties 2.8 Start-up Costs 50.3 Working Capital 27.5	Initial Catalyst and Chemicals 2.4 Interest during Constr. 152.9 Paid-up Royalties 4.2 Start-up Costs 38.6 Working Capital 25.0
Total Cap. Req. 721.7	Total Cap. Req. 706.1	Total Cap. Req. 744.6	Total Cap. Req. 1092.7

NOTE: Sidney Katell estimate for 50,000 BPD Facility not segmented by area.
Total Capital Requirement = \$702.2 MM

including coal to gasifier). The Southern Company Services and Gulf Mineral models were assumed to be in 1976 dollars. The U.S.B.M. study was increased by 5% to update its 1975 costs to mid-1976. The Parsons' study was increased by 33% to update its 1973 costs. Following Table 3-1 is Table 3-2 wherein the design assumptions which explain the cost differentials on the previous table are highlighted. To be consistent with Robert Skamser's cost guidelines, which are used throughout this report, the Plant Facility Investment includes all contractor's overheads and profits, all engineering costs, plus a 15% contingency. In Table 3-3, all costs added to the Plant Facilities to derive the Total Capital Requirement are also standardized in accordance with Skamser's guidelines. Note that Sidney Katell's estimate is included as a note to Table 3-1.

The U.S.B.M., Southern Company Services, and Parsons' models tend to support each other's capital costs but vary considerably when individual processing areas are compared. The U.S.B.M. and Parsons' studies reflect the costs of a more stringent hydrogenation requirement for a plant producing liquid fuels and a much simpler coal filtration system. On the other hand, the Bureau of Mines design calls for a much more elaborate sulfur removal system with three acid gas removal units plus fuel oil and naphtha hydrogenation units. Both the U.S.B.M. and Parsons' models require a large liquid product storage area. The Southern Company Services' model shows costs for a coal solidification section and low storage facility costs for its solid product. The Southern Company case does not include power generating facilities.

The Gulf Mineral model represents a more elaborate and self-sustaining facility. Unfortunately, very little detail is provided to explain the roughly 50% higher total investment. Two areas account for most of the cost difference: (1) Coal Preparation Section and (2) Hydrogen Plant Section. The coal preparation capital cost may include raw coal unloading and transport facilities and the hydrogen plant may produce a much higher purity product than is required in the Southern Company design.

Note that in all of the above models, the battery limits include all facilities from coal grinding and drying through product storage. Raw coal unloading, storage, and transport and product loading are not included in these presentations.

TABLE 3-2

PROBABLE CAUSE OF COST DISCREPANCIES
CAPITAL COSTS

Coal Preparation Section:

U.S.B.M. and Parsons coal ground to 1/8"

Southern Company coal ground to 50 mesh

Gulf Mineral coal unknown, model may include raw coal unloading, stockpiling and transport costs.

Coal Slurrying and Liquefaction Sections:

U.S.B.M. and Parsons models produce primarily liquid products requiring nearly twice the hydrogen. Design criteria is to maximize the hydrogenation of coal which maximizes the costs in this section.

Southern Company and Gulf Mineral models produce primarily solid SRC which requires less hydrogen and shorter digester residence time.

Filtration Sections:

U.S.B.M. and Parsons models produce primarily liquid products. Greater hydrogenation in digester section greatly reduces solids load in filter section. -- 4 Rotary Filters.

Southern Company Model - 30 Funda Filters

Gulf Minerals Model - 58 Filters

Solvent - Product Separation and Main Acid Gas Removal:

U.S.B.M. and Parsons models include an additional sulfur removal step by hydrogenating its naphtha and fuel oil by-products.

Oxygen Plant/Gasification Sections:

U.S.B.M. and Parsons models utilize only filter cake from filter section. Cake may have a much higher hydrogen content than raw coal. Gasifier functions partially as an oil gasifier.

Southern Company and Gulf Minerals models utilize mostly raw coal.

Southern Company H₂ purity about 75% by weight. Gulf Mineral H₂ purity unknown.

TABLE 3-2 (Cont'd)

Hydrogen/Fuel Gas Clean-up Section:

Southern Company and Gulf Mineral models require cleanup of gasified raw coal. Sulfur and impurities content may be much higher in these two cases than where only filter cake is fed to the gasifier.

Sulfur Recovery Section:

U.S.B.M. model - details in this section unknown. U.S.B.M. may include simply Claus unit without SCOT unit. When Sulfur Recovery cost was scaled up in Parsons case, it is comparative with Southern Company and Gulf Mineral model costs.

Waste Water Cleanup

Southern Company Waste Water Treatment is much more elaborate than U.S.B.M. and Parsons models. Southern Company case includes Phenosolvan, Lime Treatment, Chemical Treatment Trains and Ammonia Stripper.

Gulf Mineral model - waste water equipment included in utilities section costs.

Product Storage Section:

U.S.B.M. and Parsons - 2 weeks liquid storage.

Southern Company - no cost attributed to solid storage. Liquid by-products much smaller quantities

Gulf Minerals - Product storage included with General Facilities.

Utilities and General Facilities:

U.S.B.M. and Parsons include Power Plant of approximately 152 MW/hr.

Southern Company model includes bare minimum of utilities and does not include buildings, roads, service facilities.

TABLE 3-2 (Cont'd)

Plant Facilities:

U.S.B.M., Parsons and Souther Company models are within 5% of each other. Gulf Minerals model 50% greater than other models primarily because of higher costs in Coal Preparation and Hydrogen Plant sections. No details provided to explain exactly why these costs are high. Filtration and General Facilities Section also on high side of cost range established by other models.

The capital costs presented in Table 3-1 are by no means the limit to which capital cost estimates can vary. They should, however, impress upon the reader how volatile these costs can be. Design parameters in the Coal Liquefaction/Filtration area which can have an enormous effect on capital investment:

1. Recycle of unfiltered liquid effluent from dissolvers.
2. Liquid residence time in preheaters and dissolvers.
3. Number and complexity of coal filtering units.
4. Pressure required in coal dissolver units.

All five models in this analysis were based on high sulfur Eastern coals. The use of other types of coal has relatively little effect on capital cost provided the product slate remains the same and product quality varies only slightly. In the other half of the U.S.B.M. study, the same plant was re-evaluated using Wyodak coal with only a 1.4% increase in Total Investment.

At the end of this section a table has been added (Table 3-8) which lists all the Capital Costs as they appeared in their source documents prior to updating to mid-76 and scaling to a 20,000 TPD facility. This will assist the reader in breaching the gap between the costs as listed in the source literature and as it appears in Table 3-1.

TABLE 3-3
CALCULATION OF TOTAL CAPITAL REQUIREMENT
USING SKAMSER METHOD

PLANT FACILITIES

Plus

Initial Catalysts and Chemicals:

U.S.B.M. and Parsons Models: quantities and cost given.

Southern Company: quantities given, cost calculated.

Gulf Mineral Model: No details given, cost averaged from other models.

Interest During Construction:

All models calculated using formula 50% Plant Facilities x 4 years x 9% interest.

Paid-up Royalties:

All models - 5% Plant Facilities

Start-up Costs:

All models - 20% of Total Annual Gross Operating Costs

Working Capital:

All models - Sum of (1) Raw Materials Inventory of 14 days at full rate, (2) Materials and Supplies at 0.9 percent of Total Plant Investment, and (3) net receivables at 1/24 SRC and by-product revenue.

Equals

Total Capital Requirement:

All models with 10% of each other except Gulf Mineral model for reasons stated for Plant Facilities costs.

Sidney Katell model: (mid-1976). Added here because no details provided in his article concerning component costs of Total Capital Requirement.

Katell Estimate	\$ 656.7
Start-up Costs	42.8
Paid-up Royalties	<u>2.7</u>
Total Capital Req.	\$ 702.2

Estimate is for a 50,000 BPD or 20,000 TPD SRC plant.

3.2 ANNUAL OPERATING COSTS

The information contained in the five economic source documents is combined in Table 3-4 to provide a prototype operating cost breakdown of a 20,000 TPD SRC plant producing a solid product. These costs are also expressed in 1976 dollars and with a 7884 hr/year or 90% plant service factor. The operating costs have been calculated according to Skamser's "Net Operating Cost" guidelines, published in C. F. Braun & Co.'s document, "Coal Gasification Commercial Concepts Gas Cost Guidelines," Robert Skamser, C. F. Braun & Co., Alhambra, California, January 1976. No electrical generating credits are given in calculating the utility charges.

Operating costs for pollution control equipment have not been itemized separately in these analyses. In an attempt to quantify the "pollution control" costs of the five models, Table 3-5 shows a prototype annual cost for the pollution control equipment associated with a 20,000 TPD unit.

TABLE 3-4

ANNUAL OPERATING COSTS - MID-1976

<u>MATERIAL COSTS:</u>	<u>Millions \$</u>	
Coal Illinois #6 885.9 Dry Ton/hr \$25/Dry Ton	174.611	
Filter Aid 5.5 Ton/hr \$120/Ton	5.203	
Minor Chemicals Lime, H ₂ SO ₄ NaOCl, SO ₂ (liq.) Anti-Spray Dust	0.846	
Maintenance Materials 1.5% Plant Facilities	8.408	
Raw Water 540 M gal/hr 40 cents/M gal	1.703	
Operating Supplies 30% Operating Labor	1.109	
Materials Sub-total		191.880
<u>LABOR COSTS:</u>		
Operating Labor 66 men/shift, 14M/yr.	3.696	
Supervision 20% Labor	0.739	
Maintenance Labor 1.4% Plant Facility	7.847	
Administrative & Support 20% above labor cost	2.456	
Payroll Burden 35% above labor costs	5.158	
Labor Sub-total		19.896

TABLE 3-4 (Cont'd)

	<u>\$ Million</u>	
<u>ELECTRICAL POWER CONSUMPTION:</u>	<u>31.536</u>	
160,000 KWH/hr, 2.5 cents/KWH		
Electrical Sub-total		31.536
<u>FIXED COSTS:</u>		
Property Taxes and Insurance 2.7% of Plant Facilities	<u>15.134</u>	
Fixed Costs Sub-total		15.134
<u>ASH DISPOSAL:</u>		
Slag from Gasifier 122.4 Tons/hr., \$1 per Ton	<u>0.965</u>	
Disposal Sub-total		<u>0.965</u>
TOTAL GROSS OPERATING COST		<u>259.411</u>
20 yr. Straight Line Depreciation		28.025
Annual Operating Cost Incl. Depreciation		287.436
<u>BY-PRODUCT CREDITS:</u>		
Oil Products 7,925 BPD, \$16.80/Barrel	(43.736)	
Sulfur 624 TPD, \$25/Ton	(5.125)	
Steam	<u>no credit</u>	
By-Product Sub-total		(48.861)
TOTAL NET OPERATING COST		<u>238.575</u>
Annual SRC Output (MM tons)		3.785
Thermal Efficiency		78%

TABLE 3-5

POLLUTION CONTROL COSTS WITHIN
COMPARATIVE ECONOMIC MODELS - MID 1976

<u>POLLUTION CONTROL UNITS</u>	<u>MM Dollars</u>
Benfield Unit	3.0
Sulfur Recovery Units (Claus & SCOT)	16.0
Waste Water Treatment	10.0
Cryofining & Stabilizing	6.0
Selexol Unit (included in H ₂ manufacture Investment	-
Facilities Investment	\$ 35.0
<u>ANNUAL OPERATING COSTS</u>	<u>MM Dollars</u>
Operating Supplies	
Lime	
Anti-dust Powder	
Claus Catalysts	0.400
Sewage Water Chemicals	
Diatomaceous Earth	
Maintenance Materials - 1.5% PFI	0.525
Operators	0.392
7/Shift, 14M/Oper.	
Supervision, 20% Operating Labor	0.078
Maintenance Labor, 1.4% PFI	0.490
Adm. & Support, 20% above	0.192
Payroll Burden, 35% above	0.403
Purchased Power	1.500
Water	0.050
Property Taxes and Insurance, 2.7% PFI	0.945
Annual Operating Cost	<u>\$ 4.975</u>

3.3 COST OF PRODUCT

The cost of the main product SRC based on the prototype SRC operating cost (Table 3-4) is developed in Table 3-6 using Skamser's methods. The Southern Company model is used for the capital cost information. The main product is solid SRC.

The major factor affecting these product costs, other than the total capital and annual operating costs, is the thermal efficiency of the model. This efficiency ratio includes the Btu value of the main product and all By-products divided by the raw coal input plus the Btu equivalent of any purchased electrical power. The efficiency in the prototype model is approximately 73% but can drop as low as 60% in some cases.

TABLE 3-6

COST OF MAIN PRODUCT FOR 20,000 TPD
SRC PLANT PRODUCING SOLID PRODUCT - MID 1976

1. UTILITY FINANCING

C: Total Capital Requirement	=	\$ 744.2 MM
W: Working Capital	=	27.5 MM
N: Total Net Operating Cost	=	238.6 MM
G: Annual Btus in Product	=	121.1 Trillion
d: Debt Fraction	=	75%
i: Interest Rate	=	9%
r: Return on Equity	=	15%
p: Return on Rate Base	=	10.5%

1st Year's Product Cost = \$3.10/MM Btus

Average Product Cost = \$2.71/MM Btus

2. DISCOUNTED CASH FLOW FINANCING

I: Plant Facility Investment	\$ 560.5 MM
S: Start-up Costs	54.1 MM
W: Working Capital	27.5 MM
N: Total Net Operating Cost	238.6 MM
G: Annual Btus in Main Product	121.1 Trillion

Product Cost = \$3.23/MM Btus

3.4 SENSITIVITY ANALYSIS

Using the prototype SRC model developed in the annual operating and main product cost sections, it is now possible to run a sensitivity analysis upon the main product cost. Sensitivity analysis in this case refers to the process of changing one underlying assumption in the model and then working it through to see what effect the changed condition has on the product cost. For example, a sensitivity analysis would answer the question: What would be the effect on product cost if the scale of the plant was changed from 20,000 TPD to 10,000 TPD assuming the same thermal efficiency, etc.? In such an example, both capital and operating costs are altered and, in turn, the product cost is changed.

Listed in Table 3-7 are some of the sensitivity analyses worked through using the prototype model. Included in the table is an indication of how large a modification was made in each underlying parameter and approximately how much it affected the product price.

TABLE 3-7
SENSITIVITY ANALYSIS - PROTOTYPE MODEL

Product Cost - \$2.37/MM Btu

UNDERLYING PARAMETERS	BASE CASE	DOWNWARD ADJUSTMENT		UPWARD ADJUSTMENT	
		NEW VALUE	PRODUCT COST	NEW VALUE	PRODUCT COST
Raw Coal Price	\$25/T	\$20/T	- 12%	\$30/T	+ 12%
Plant Capacity	20,000 T/D	10,000 T/D	+ 12%	30,000 T/D	- 12%
Capital Overrun	100%	80%	- 11%	120%	+ 11%
H ₂ Usage Coal Wt. %	1.8%	1.3%	- 4%	2.3%	+ 4%
Filter Rate	7.0 $\frac{\text{GPH}}{\text{H}_2}$	5.5 $\frac{\text{GPH}}{\text{H}_2}$	+ 2.5%	8.5 $\frac{\text{GPH}}{\text{H}_2}$	- 23%
Solvent/Coal Ratio	1.6	1.5	- 2.5%	2.5	+ 23%
Interest Rate	10%	8%	- 3%	12%	+ 3%
Plant Life	20 Yr.	15 Yr.	+ 3%	30 Yr.	- 2.5%
Debt/Equity 10%/20%	65/35	50/50	+ 8%	90/10	- 11%

TABLE 3-8

CAPITAL COSTS FOR U.S.B.M./PARSONS/SOUTHERN COMPANY/GULF MINERALS

MODELS AS THEY APPEAR IN SOURCE DOCUMENTS

U.S.B.M.	PARSONS	SOUTHERN COMPANY	GULF MINERAL RESOURCES
<u>Document:</u> ERDA - 76-55 Bureau of Mines - March 1976	<u>Document:</u> National Tech. Info. Serv. PB-234-165, Sept. 1973 PB-234-321, Dec. 1973 PB-238-529, Dec. 1974	<u>Document:</u> "Economics of SRC" Richard H. Chastain Southern Company Services, Inc. Nov. 1976	<u>Document:</u> Presentation at 4th Annual Int'l Conf. on Coal Gasification, Liquefaction and Conversion. B. K. Schmid, D. M. Jackson. August 1977
<u>Case:</u> Illinois #6 Coal	<u>Case:</u> --	<u>Case:</u> --	<u>Case:</u> SRC-1
<u>Scale:</u> 20,000 TPD Dry Coal Feed No Raw Coal to Gasifier	<u>Scale:</u> 10,000 TPD Dry Coal Feed No Raw Coal to Gasifier	<u>Scale:</u> 20,000 TPD Dry Coal Feed 1,260 TPD Dry Coal to Gasifier	<u>Scale:</u> 27,076 TPD Dry Coal Feed 2,924 TPD Dry Coal to Gasifier
<u>Time Factor:</u> Mid-1975 dollars Cost Index = 182.4	<u>Time Factor:</u> Mid-1973 dollars Cost Index = 144.7	<u>Time Factor:</u> Mid-1976 dollars Cost Index = 192.1	<u>Time Factor:</u> Mid-1976 dollars Cost Index = 192.1
Contingency: 20%	Contingency: 15%	Contingency: 15%	Contingency: 15%

Table 3-8 (Cont'd.)

U.S.B.M.		PARSONS		SOUTHERN COMPANY		GULF MINERAL RESOURCES	
	\$ Million		\$ Million		\$ Million		\$ Million
Coal Preparation	15.4	Coal Preparation (package unit)	4.0	Coal Preparation	30.8	Coal Preparation	81.0
Coal Slurry Pumping	1.5	Coal Slurry Pumping	0.9	Coal Slurry Dissolving		Hydrogenation	
Coal Liquefaction	143.8	Coal Liquefaction	88.5	Benfield		Hydrogen Recycle	
Dissolver Acid Gas Rem.	55.0	Dissolver Acid Gas Rem.	20.2	Cryofining			
				Oil Absorption			
Sub-total	200.3	Sub-total	105.6	Sub-total	156.5	Sub-total	198.0
Filtration	7.6	Filtration	4.0	Filtration	122.3	Filtration	172.0
Product Distillation	8.1	Product Distillation	2.4	Solvent Degassing and Recovery		Fractionation	
Fuel Oil Hydrogenation	60.5	Fuel Oil Hydrogenation	20.8			Product Solidification	
Naphtha Hydrogenation	5.3	Naphtha Hydrogenation	2.1				
Acid Gas Removal	20.8	Acid Gas Removal	5.8				
Sub-total	94.7	Sub-total	31.1	Sub-total	50.3	Sub-total	49.0
Gasification	19.1	Gasification	17.1	K-T Gas Producer	73.3	Gasifier	
Oxygen Plant	25.0	Oxygen Plant (Package Unit)	15.9	Air Separation	28.9	Hydrogen Plant	307.0
Fuel Gas Sulfur Removal	4.4	Fuel Gas Sulfur Removal	2.0	Acid Gas Removal	22.7	Gas and Secondary Recovery	61.0
Shift Converter	16.5	Shift Converter	5.5	Shift and Purification	19.1		
CO ₂ Removal	9.8	CO ₂ Removal	2.5				
Methanation	0.8	Methanation	0.4				
Sub-total	31.5	Sub-total	10.4	Sub-total	41.8		
Sulfur Recovery	4.2	Sulfur Recovery	7.9	Claus & SCOT	14.0	Sulfur Recovery	20.0
Waste Water Cleanup	3.5	Waste Water Cleanup	1.6	Waste Water Treatment	13.0	Waste Water	--
Product Storage	16.0	Product Storage	9.1	Solvent Storage & Shipping	7.2	Product Storage	--
Power Plant	48.9	Power Plant	42.6	Utilities System & Offsites		Utilities	99.0
Plant Utilities	50.1	Plant Utilities	17.1			General Facilities	77.0
General Facilities	35.0	General Facilities	3.9				
Sub-total	134.0	Sub-total	63.6	Sub-total	22.4	Sub-total	176.0
Plant Facility	551.3	Plant Facility	270.0	Plant Facility	560.5	Plant Facility	1064.0

4. TECHNICAL FEASIBILITY

We have seen that the SRC-I process has been demonstrated at both the Wilsonville and Fort Lewis pilot plants. To date, five coals have been tested, viz.,

Kentucky #9 & 14
Pittsburgh #8
Illinois #6
Illinois-Monterey (high sulfur)
Wyoming-Amax

Currently work is progressing on Indiana V coals. Bituminous coals perform well under some general operating conditions:

Solvent to Coal Ratio	1.6:1
Dissolver Temperature	825°F
Dissolver Pressure	1700 psig
Reactor Space Velocity	75 lb/hr x ft ³
Hydrogen Consumption	2% MF coal feed

The SRC product, regardless of the feed coal, has essentially the same properties and meets EPA standards as utility fuel.

High Heating Value	16000 Btu/lb
Melting Point	300°F
Ash Content	Less than 0.1%
Sulfur Content	Less than 0.8%

The process can operate in total solvent balance. This feature, along with minimum hydrogen consumption as compared to other coal liquefaction processes, offers favorable economics.

The question then is, "What are the unsolved problems which would prevent a commercial SRC plant from being technically feasible?" Some difficulties remain with the slurry pump metallurgy and size limitations, slurry preheater design, precoat filter, filter cake disposal, product solidification and control valve life.

Pumps remain a major operation and maintenance problem. Some of the pumps have an uneconomically short life. Better coating material and experience to date is expected to help alleviate this situation.

Both the Wilsonville and Fort Lewis plants have helical coils in the slurry preheaters and neither unit can be used to gather design data for scale-up. The scale-up of a three-phase flow, direct-fired process heater is always a challenge, especially when considering the fact that heat input varies directly with tube diameter whereas heat load varies as the diameter squared for the same temperature difference. Another consideration is the pressure drop through the tube. If all hydrogen were added ahead of the heater, highest pressure drop would be obtained. To circumvent this, hydrogen addition before and after the heaters may be considered. A careful design based on current experience will result in a workable heater, but a confirmed design will have to await the operation of the first commercial unit.

Mechanical operation of the Funda precoat filter has been satisfactorily demonstrated in a batch mode. However, some operational difficulties remain with shaft seals and screen maintenance. For a commercial-size unit, the manufacturer proposes to install washing jets to alleviate screen blinding problems. Filter cake is currently dried on the leaves after washing. This has resulted in a cake with less than 5% solvent and eliminated additional drying equipment, but increased the filter cycle time somewhat. Disposal of filter cake in an acceptable manner may involve its use for gasification. Texaco has made test runs with H-coal residue, but more work needs to be done. Among peculiar problems associated with scale-up of the filter to commercial size are the seals and the size of the shaft and mechanism of cake removal for large diameter units.

The two systems used for product solidification -- the Rexnord vibrating plate and Sandvik belt -- require a large number of units. Neither of these systems is very popular. There is no serious attempt being made to find alternative schemes. Tests done on a pencil pitch method in England were not promising.

These difficulties point to the need for continued intense research and development work in several areas. However, the problems do not appear to be insurmountable. It appears that an SRC-I plant could be built which would operate on a commercially reliable basis. However, the next immediate step toward commercialization is to build a demonstration plant which would allow mechanical development of several critical pieces of equipment and would lead to multiple train commercial plants.

5. SUMMARY

The purpose of this study in broad terms was: 1) to conduct a literature search on information relative to the Solvent Refined Coal-I Process; 2) summarize reported results of the operation of SRC pilot plants at Fort Lewis and Wilsonville; 3) describe the conceptual design of a commercial plant to process 20,000 TPD of coal; and 4) to compare those economic studies of the SRC plant which are published in the literature.

Literature Search

The literature search was primarily based on NTIS, ERDA and COMPENDEX data banks. Most of the research and development work is supported either by U.S. Government Agencies (OCR, ERDA, EPA, etc.) or EPRI. Extensive studies have been made on the hydroliquefaction of bituminous and subbituminous coals. Little information exists regarding solids separation, char utilization, process equipment development and aqueous waste effluents from the two pilot plants.

Work by Air Products and Chemicals, Oak Ridge National Laboratory and Dow has been reported on SRC product upgrading to petrochemical feed. Characterizations of SRC and intermediate products have been well documented.

Many studies and in-depth analyses are reported on the environmental concerns of coal liquefaction processes. However, only a limited amount of data on aqueous effluent characteristics were found in literature.

Economics of the SRC process continue to be studied and updated. The subject has received considerable attention from private industry in recent times.

Information generated at the Wilsonville and Fort Lewis pilot plants is now available in published reports. In addition, ERDA has published several reports on engineering and economic studies of the SRC process.

The literature search presented here goes back to the mid sixties, and in view of continuous strides being made in SRC process research and development, the references are presented in chronological order.

SRC Pilot Plants

A brief history and current plans of the Wilsonville and Fort Lewis pilot plants are given in the body of this report, followed by a summary of pilot plant operating data and evaluation.

The Wilsonville SRC pilot plant has been operated with five different coals, bituminous and subbituminous. A survey of operating conditions of earlier runs was compared with recent runs which simulate conditions at the Fort Lewis pilot plant. The effects of various coals on plant operating conditions and yield data were evaluated. Process conditions such as temperature, pressure, hydrogen consumption, space velocity, etc. were evaluated in view of their effects on process yields. Operation of the Funda filter was discussed. Equipment problems and plant modifications were reviewed. These data were compared with Fort Lewis data in the SRC-I mode.

Data from the Fort Lewis pilot plant, when operated in the SRC-I mode, were summarized. Operating conditions and results of eleven runs were reported. Models were developed for component yields from multiple linear regression analyses of these data. Good fit seems to occur with total hourly space rate and dissolver temperature.

Commercial Plant Design

TRW, Inc. conducted an evaluation of data from the two pilot plants for Kentucky #9 & 14 coal and concluded that data from either plant can be used for scale up. Conceptual process design for a 20,000 tons per day coal feed commercial plant was prepared based on these observations. A process description, block flow diagrams and material balances for each of the process areas, hydrogen manufacture and waste treatment systems were

given. A material and energy balance was prepared and energy efficiency calculated. A thermal efficiency of 73% or higher can be realized when hydrogen manufacture is included in the plant scheme.

Product Characteristics

A discussion of product SRC as a solid and a liquid fuel and the results of a burn test at Plant Mitchell in Albany, Georgia were given. Properties and combustion characteristics of SRC have proven it to be an ideal utility fuel.

Raw Materials Required

Primary raw materials for the SRC plant are coal and precoat material. The effect of various types of coals on the process conditions, yield, and plant economics were discussed.

Equipment Size and Delivery

The SRC process, because of its large economic size and severe processing conditions, makes the design of equipment difficult in terms of size, materials of construction, and delivery. Such equipment includes the slurry pumps, slurry preheater, dissolver, filter and product solidification units. Special aspects associated with the design of this equipment were discussed.

Process Economics

Published economics on the SRC process by the U.S. Bureau of Mines, R. M. Parsons, Southern Company Services and Gulf Minerals were compared. Capital costs were adjusted to make the various studies comparable. Operating cost, product cost and product cost sensitivity analyses were also reported based on the published data.

Technical Feasibility

A review of the present state of the art of the SRC process and risks associated with commercialization of the process were discussed.

6.1 COAL LIQUEFACTION RESEARCH AND DEVELOPMENT

A large portion of these references is comprised of progress reports from the following organizations:

1. Pittsburgh and Midway Coal Mining Co. on SRC Process Studies
2. Dow Chemicals Co. on chemicals from coal
3. Oak Ridge National Laboratory on coal technology programs
4. North Dakota University on Project Lignite (operation of lignite liquefaction PDU)
5. North Dakota University on chemistry of lignite liquefaction
6. Penn State University on dependence of coal liquefaction on coal characteristics..
7. Hydrocarbon Research Institute on liquefaction studies of several coals (Work done for EPRI)

There are several patents on SRC process listed. Two references describe short residence time liquefaction process. Also included are papers from University of Utah on liquefaction of Western coals. Papers from Colorado School of Mines, University of Colorado and Auburn University report basic research on coal liquefaction.

6.1.1

SOLVENT REFINED COAL (SRC) PROCESS

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.

Monthly rept. nos. 1 thru 13, Oct 66-Oct 67..

Oct 67 308p

Contract: DI-14-01-0001-496

Monitor: 18

See also Monthly rept. nos. 14-27, PB-233 278

Abstract: These monthly reports trace the progress of the Solvent Refined Coal (SRC) process developed by the Pittsburg and Midway Coal Mining Co. under contract to the Office of Coal Research since 1966. The process will undergo testing in a pilot plant recently completed near Tacoma, Wash. at a cost of \$18 million. In the SRC process, coal is first dissolved under moderate hydrogen pressure in a heavy aromatic solvent derived from the process. The resultant coal solution is filtered to remove ash and a small amount of insoluble organic material and fractionated to recover the solvent. The main product from the process is a heavy organic material called solvent refined coal. Smaller quantities of hydrocarbon gases and light distillate liquids are also produced.

NTIS PB-233 277/3

6.1.2

SOLVENT REFINED COAL (SRC) PROCESS

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.

Monthly rept. nos. 14 thru 27, Nov 67-Dec 68.

Dec 68 314p

Contract: DI-14-01-0001-496

Monitor: 18

See also Monthly rept. nos. 1-13, PB-233 277 and Monthly rept. nos. 28-39, PB-233 279

Abstract: These monthly reports trace the progress of the Solvent Refined Coal (SRC) process developed by the Pittsburg and Midway Coal Mining Co. under contract to the Office of Coal Research since 1966. The process will undergo testing in a pilot plant recently completed near Tacoma, Wash., at a cost of \$18 million. In the SRC process, coal is first dissolved under moderate hydrogen pressure in a heavy aromatic solvent derived from the process. The resultant coal solution is filtered to remove ash and a small amount of insoluble organic material and fractionated to recover the solvent. The main product from the process is a heavy organic material called solvent refined coal. Smaller quantities of hydrocarbon gases and light distillate liquids are also produced.

NTIS PB-233 278/1

6.1.3

COAL LIQUEFACTION

Nelson, Edwin F. (Universal Oil Products Co.) U.S. 3,477,941

11 Nov 1969, Appl. 25 Jan 1968; 6 pp

Abstract: Coal is liquefied by solvent extension using a H-donor selective solvent. Particulate coal of relatively large diameter is mixed with solvent and passed into an H₂ gas stream in an eduction device. The admixture and H₂ are propelled against impact means located in the lower end of a vertically disposed digestion zone containing liquid solvent under pulverization conditions sufficient to break down coal into relatively small particles. The H₂ acts as a carrying medium for the solvent and coal and aids in the conversion of the solid coal to liquid ext. and, in addition partially hydrogenates the solvent present in the digestion zone. The product is passed through the liquid solvent in the digestion zone in an upwardly flowing manner under conditions sufficient to substantially liquefy the coal. A stream containing liquefied coal is withdrawn from the upper end of the zone and a stream of ash and nonliquid materials are withdrawn from the bottom. Hydrocarbon products are separated from the liquefied coal. The liquefying conditions include superatm. pressure, 300-500^o, solvent-to-coal ratio from 0.2 to 10, and a residence time from 30 sec to 5 hr sufficient to dissolve coal into the solvent such that a total in excess of 50 wt. % of the moisture and ash-free solid particulate coal is liquefied. At least a portion of the solvent is selected from tetrahydronaphthalene, decahydronaphthalene, biphenyl, methynaphthalene and dimethylnaphthalene.

6.1.4

SOLVENT REFINED COAL (SRC) PROCESS

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.

Monthly rept. nos 28 thru 39, Jan-Dec 69

Dec 69 337 p

Contract: DI-14-01-0001-496

Monitor: 18

See also Monthly rept. nos. 14-27, PB-233 278 and Monthly rept. nos. 40-48 PB-233 280.

Abstract: These monthly reports trace the progress of the Solvent Refined Coal (SRC) process developed by the Pittsburg and Midway Coal Mining Co. under contract to the Office of Coal Research since 1966. The process will undergo testing in a pilot plant recently completed near Tacoma Wash., at a cost of \$18 million. In the SRC process, coal is first dissolved under moderate hydrogen pressure in a heavy aromatic solvent derived from the process. The resultant coal solution is filtered to remove ash and a small amount of insoluble organic material and fractionated to recover the solvent. The main product from the process is a heavy organic material called solvent refined coal. Smaller quantities of hydrocarbon gases and light distillate liquids are also produced.

NTIS PB-233 279/9

6.1.5 SOLVENTS USED IN THE CONVERSION OF COAL

J. M. Angelovich, G. R. Pastor, and H. F. Silva
Ind. Eng. Chem, Process Des. Develop., Vol. 9. No. 1,
Jan. 1970

Abstract: The results of an experimental study on the effectiveness of solvents in the liquid-phase catalytic hydrogenation of a subbituminous Wyoming coal in a batch reactor have been correlated using Prausnitz's concept of a nonpolar solubility parameter. Kiebler's experimental data from a solvent extraction study of a Pittsburgh seam coal have also been correlated using this parameter. Solvents with a nonpolar solubility parameter of approximately 9.5 appeared to be most effective in both studies. Analysis of data from Australian coal extraction studies and Japanese coal swelling studies showed similar results. This suggests that the nonpolar solubility parameter may be useful as an additional tool for screening solvents proposed for coal liquefaction of extraction processes.

6.1.6 COAL LIQUEFACTION BY USE OF A SELECTIVE SOLVENT

Nelson, Edwin F. (Universal Oil Products Co.) U.S.3,488,278
06 Jan 1970, Appl. 25 Jan 1968; 6 pp.

Abstract: Coal is liquified in a continuous countercurrent manner by using a selective solvent. Coal is passed into the upper end of the vertical liquefying zone at 300-500° and 500 psig. Coal solvent is introduced at a series of spaced points from the lower end of the liquefying zone. Solvent contg. dissolved coal is removed from the upper end of the zone; a residue contg. ash and undissolved material is removed from the bottom. It is preferred that 50-90% by vol. of lean solvent entering the extn. zone be introduced through the uppermost point; 3 introduction points are used and the amt. of solvent is in a 70:20:10 ratio. The 10% amt. of solvent enters the lowest point. Added H₂ and hydrogenation catalyst (Pd on Al₂O₃ or Co-molybdate) are used in the extn. zone to aid in converting to liq. hydrocarbons. Suitable solvents are Tetralin, Decalin, biphenyl, or other H-donor type solvents. Specific hydrotreating during extn, is to use j-factor analysis for detg. the degree to which H₂ has added to the solvent. Some j-factors from the formula (C_nH_{2n-j}) are: alkyl benzenes and C₆H₆, indans and Tetralins 8, indenenes 10, and alkylnaphthalenes and naphthalenes 10.

6.1.7

SOLVENT EXTRACTION OF COAL

Nelson, Edwin F. (Universal Oil Products Co.) U.S. 3,505,202
07 Apr 1970, Appl. 26 June 1967; 5 pp

Abstract: A method for liquefying coal by solvent extn. by using a H-donor solvent, such as Tetralin, is described. A coal-solvent mixt. is pulverized to -8 Tyler mesh size at 300-500° and 1-670 atm. The solvent-coal wt. ratio was 0.2-10:1. The crushed coal-solvent mixt. was then transferred to a digestion zone and held under the above conditions for 30 sec to 5 hr. An excess of 50 wt. % moisture and-ash-free coal was liquefied.

6.1.8

SOLVENT EXTRACTION LIQUEFACTION OF COAL

Nelson, Edwin F. (Universal Oil Products Co.) U.S. 3,505,202
07 Apr 1970, Appl 26 Jun 1967; 166 pp

Abstract: A H-donor selective solvent is used for the title process. Thus pulverized coal with a solvent such as Tetralin, Decalin, biphenyl, methylnaphthalene, or dimethynaphthalene gives a liquefied coal ext. dissolved in the solvent. After sepn. of the liq. coal ext. from the H₂ deficient solvent, the solvent is regenerated by selective catalytic hydrogenation.

6.1.9

COAL LIQUEFACTION

Nelson, Edwin F. (Universal Oil Products Co.) U.S. 3,503,864
31 May 1970, Appl 29 Dec 1967; 6 pp

Abstract: Liq. hydrocarbons are prepared from coarse particulate coal by solvent extn., hydrogenation and coking. Coarse coal is mixed with a solvent comprising H-donor aromatic hydrocarbons (e.g., Tetralin or Decalin) and fed to a pulverizing zone at 300-500° and from 1 atm to 10,000 psig (solvent-coal 0.2:10) with 1000-10,000 ft³H₂/bbl mixture to reduce the coal to -8 Tyler screen and partially dissolve it. The pulverized product is passed into a digestion zone at 300-500° and from 1 atm to 10,000 psig (solvent-coal 0.2:10) for 0.1 to 300 min to liquefy 50% moisture and ash-free coal. The liquid coal ext. is passed into a delayed coker at 400-800° to produce 5-30% coke; liq. hydrocarbons are recovered from the coker.

6.1.10
SOLVENT REFINED COAL (SRC) PROCESS

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.
Monthly Reports Nos. 40 thru 48, Jan.-Sep. 70
Sep 70 341p
Contract: DI-14-01-0001-496
Monitor: 18
See also Monthly rept. nos 28-39, PB-233 279 and Monthly
rept. nos. 49-55, PB-233 281

Abstract: These monthly reports trace the progress of the Solvent Refined Coal (SRC) process developed by the Pittsburg and Midway Coal Mining Co. under contract to the Office of Coal Research since 1966. The process will undergo testing in a pilot plant recently completed near Tacoma, Wash., at a cost of \$18 million. In the SRC process, coal is first dissolved under moderate hydrogen pressure in a heavy aromatic solvent derived from the process. The resultant coal solution is filtered to remove ash and a small amount of insoluble organic material and fractionated to recover the solvent. The main product from the process is a heavy organic material called solvent refined coal. Smaller quantities of hydrocarbon gases and light distilled liquids are also produced.

NTIS PB-233 280/7

6.1.11
COAL LIQUEFACTION USING DUAL SOLVENT EXTRACTION

Corey, Richard S.; Riedl, Frederick J.; Campbell, Douglas R.
(Universal Oil Products Co.) U.S. 3,535,224
20 Oct 970, Appl. 25 Jun 1968; 4 pp.

Abstract: A solvent-extn. process is described for producing H₂ enriched hydrocarbonaceous products from particulate coal. The coal is treated with a polycyclic aromatic solvent, such as Tetralin, and a secondary solvent, such as dichloronaphthalene, and H₂ at 250°-500° and ~2000 psig. About 50 wt. % of the coal is converted to liq. coal extract having the following comp.: S 0.72, benzene insol. 8.04, and H 7.07 wt. % and a mol. wt. 396.

6.1.12
COAL LIQUEFACTION

Riedl, Frederick J.; Corey, Richard S.; Svacha, Roy E. (Universal Oil Products Co.) U.S. 3,536,608, 27 Oct 1970
Appl. 20 Aug. 1968; 4 pp.

Abstract: Colloidal-size coal particles are treated with a solvent, e.g. Tetralin or Decalin, in the presence of H₂ and liq. hydrocarbons are recovered from the coal ext. The conversion of coal crushed to 95% <2 μ was 3% higher than coal crushed to an av. particle diam. of <14-mesh (Tyler screen); the % H₂ in the liq. coal ext. was 7.01 and 6.81, resp.

6.1.13

SOLVENT REFINED COAL (SRC) PROCESS

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.

Monthly rept. nos. 49 thru 55; Oct 70-Apr 71

Apr 71 317 p

Contract: DI-14-01-0001-496

Monitor: 18

See also Monthly rept. nos. 40-48, PB-233 280 and Monthly rept. nos. 56-61, PB-233 282.

Abstract: These monthly reports trace the progress of the Solvent Refined Coal (SRC) process developed by the Pittsburg and Midway Coal Mining Co. under contract to the Office of Coal Research since 1966. The process will undergo testing in a pilot plant recently completed near Tacoma, Wash., at a cost of \$18 million. In the SRC process, coal is first dissolved under moderate hydrogen pressure in a heavy aromatic solvent derived from the process. The resultant coal solution is filtered to remove ash and a small amount of insoluble organic material and fractionated to recover the solvent. The main product from the process is a heavy organic material called solvent refined coal. Smaller quantities of hydrocarbon gases and light distillate liquids are also produced.

NTIS PB-233 281/5

6.1.14

COAL LIQUEFACTION BY THREE-STAGE SOLVENT EXTRACTION

Gatsis, John G. (Universal Oil Products Co.) U.S. 3,583,900

(Cl. 208-8; C 10g), 08 Jun 1971, Appl. 29 Dec 1969; 11 pp.

Abstract: Crushed bituminous coal (1000 g) containing 5.83% H and 84.7% C was mixed with 3000 g tetrahydronaphthalene at 25° for 5 hr, extended at 430°, 2000 psig, 0.5 hr residence time for coal, and 4000 ft³ H₂/bbl mixture to give a liquid product containing H 7.18, C 87.70, and solids 0.50%; extended with C₇H₁₆ at C₇H₁₆ liquid/coal ratio of 5:1 at 150° for 0.5 hr to give an upper phase containing H 8.68 and C 83.75%, and a lower phase containing H 6.53 and C 83.3% on a C₇H₁₆-free basis. The lower phase was extended further with C₆H₆ at 150°.

6.1.15

SOLVENT EXTRACTION METHOD FOR LIQUEFYING COAL

Sunagel, George R.; Corey, Richard S.; Riedl, Frederick J.; Gleim, William K. T. (Universal Oil Products Co.) U.S. 3,598,717 (Cl.208-8; C 10g), 10 Aug 1971, Appl. 25 Jun 1968; 7 pp.

Abstract: A 2 stage solvent-extension method is used for converting pulverized coal into liquid coal extension. Pulverization of the coal results in an increase in the efficiency of the operation. In the 1st stage, solvents, such as polyaromatic hydrocarbons, alkyl naphthalenes, anthracene oil, or partially hydrogenated aromatics, are used. These boil between 260° and 425°. The solvent should be able to transfer H₂ to the coal during the liquefying step. The H-rich components and the H-lean components are produced in separate product streams. The liquefied coal stripped of the solvent is then extended with a ketone or monocyclic aromatic hydrocarbon to produce a H-rich extension fraction and a H-lean extension phase. The H-rich fraction is recovered and used as a source of chemicals and liquid fuels. The H-lean fraction may be used for plant fuel and (or) as a source of addl. H₂ in a H₂O-gas reaction.

6.1.16

SOLVENT REFINED COAL (SRC) PROCESS

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.

Monthly rept. nos. 56-61, May 71-Oct 71

Oct 71 320 p

Contract: DI-14-01-0001-496

Monitor: 18

See also Monthly rept. nos. 49-55, PB-233 28; and Monthly rept. nos. 62-67, PB-233 283.

Abstract: These monthly reports trace the progress of the Solvent Refined Coal (SRC) process developed by the Pittsburg and Midway Coal Mining Co. under contract to the Office of Coal Research since 1966. The process will undergo testing in a pilot plant recently completed near Tacoma, Wash., at a cost of \$18 million. In the SRC process, coal is first dissolved under moderate hydrogen pressure in a heavy aromatic solvent derived from the process. The resultant coal solution is filtered to remove ash and a small amount of insoluble organic material and fractionated to recover the solvent. The main product from the process is a heavy organic material called solvent refined coal. Smaller quantities of hydrocarbon gases and light distillate liquids are also produced.

NTIS PB-233 282/3

6.1.17

MULTIPLE-STAGE PROCESS FOR PRODUCING LIGHT LIQUIDS FROM COAL

Bull, Willard C.; Schmid, Bruce K. (Gulf Research and Development Co.)
U.S. 3,640,816, 08 Feb 1972, Appl. 883,182,08
Dec 1969; 8 pp.

Abstract: Powdered coal slurry is hydrogenated at 350-425°/500-3000 psig without catalyst in a multistage process to produce a reaction mixture containing gases, light liquids and heavy bottoms. The liquids are directed to a combination separator and distn. unit while the heavy bottoms that are not yet converted are treated in a further stage with light liqs. due to further hydrogenation of the heavy bottoms being removed at each stage. Remaining bottoms are moved on to succeeding stages and subjected to more severe conditions of treatment. Heavy bottoms may be recycled to preceding stages. The removal of light liqs. at each stage prevents their being cracked to undesirable low mol. wts.

6.1.18

SOLVENT REFINED COAL (SRC) PROCESS

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.

Monthly rept. nos. 62 thru 67, Nov 71-Apr 72

Apr 72 340p

Contract: DI-14-01-0001-496

Monitor: 18

See also Monthly rept. nos. 56-61, PB-233 282 and Monthly rept. nos. 68-74, PB-233 284

Abstract: These monthly reports trace the progress of the Solvent Refined Coal (SRC) process developed by the Pittsburg and Midway Coal Mining Co. under contract to the Office of Coal Research since 1966. The process will undergo testing in a pilot plant recently completed near Tacoma, Wash., at a cost of \$18 million. In the SRC process, coal is first dissolved under moderate hydrogen pressure in a heavy aromatic solvent derived from the process. The resultant coal solution is filtered to remove ash and a small amount of insoluble organic material and fractionated to recover the solvent. The main product from the process is a heavy organic material called solvent refined coal. Smaller quantities of hydrocarbon gases and light distillate liquids are also produced.

NTIS PB-233 283/1

6.1.19

COAL LIQUEFACTION

Urban, Peter (Universal Oil Products Co.) U.S. 3,796,659

12 Mar 1972 Appl. 274,145, 24 Jul 1972; 5 pp

Abstract: The ash content of the coal sample, a seam coal, pulverized to pass through a 200-mesh Tyler screen, contained ash 10.18, N 1.32, S 3.34, total O 9.54, free water 4.00, volatiles 89.72, C 64.45, H 5.25 and dry ash 10.70 wt.%. The pulverized coal (100 g) and 400 g water were sealed in an 1850 cm³ rocking autoclave with atm. of pressure 70 atm. heated to 350° for 6 hr. and cooled to room temp. and pressure 62 atm. The excess pressure was released and the remaining contents of the autoclave were removed. The effluent consisted of a water phase and a hydrocarbonaceous phase, which solidified at 100° and was sepd. from the water phase by decantation and dried. The hydrocarbonaceous materials were extd. with benzene. The benzene-sol fraction contained 30 wt.% C in the original 100 g of coal charged to the autoclave.

6.1.20

CONCISE DICTIONARY-HANDBOOK ON FUELS

Army Foreign Science and Technology Center Charlottesville, Va.

AUTHOR: Kushnirenko, K. F.

21 Aug 72 705p

Rept. No. PSIC-HT-23-1019-72

Project: FSTC-T023012301

MONITOR: 19

Trans. of mono. Kratkii Slovar-Spravochnik po Goryuchemu, Moscow, 1971
167p, by Elliott.

Abstract: The dictionary-handbook contains short definitions for several of the most widely used terms concerning the transportation, opening, storage, quality control and use of fuels, lubricating materials, and special liquids. Illustrations and tables are used for clarification and fuller information. Tables dealing with properties and characteristics of materials, and technical specifications of items and equipment are given

NTIS AD 750 484

6.1.21
SOLVENT REFINED COAL (SRC) PROCESS

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.

Monthly rept. nos. 68 thru 74.

Nov 72 352p

Contract: DI-14-01-0001-496

Monitor: 18

See also Monthly rept. nos. 62-67, PB-233 283 and Monthly rept. Nos. 75-79, PB-233 285.

Abstract: These monthly reports trace the process of the Solvent Refined Coal (SRC) process developed by the Pittsburgh and Midway Coal Mining Co. under contract to the Office of Coal Research since 1966. The process will undergo testing in a pilot plant recently completed near Tacoma, Wash., at a cost of \$18 million. In the SRC process, coal is first dissolved under moderate hydrogen pressure in a heavy aromatic solvent derived from the process. The resultant coal solution is filtered to remove ash and a small amount of insoluble organic material and fractionated to recover the solvent. The main product from the process is a heavy organic material called solvent refined coal. Small quantities of hydrocarbon gases and light distillate liquids are also produced.

NTIS PB-233 284/9

6.1.22
SOLVENT REFINED COAL (SRC) PROCESS

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.

Monthly rept. nos. 75-79, Dec 72-Apr 73

Apr 73 358p

Contract: DI-14-01-0001-496

Monitor: 18

See also Monthly rept. nos. 68-74, PB-233 284 and Monthly rept. nos. 80-83, PB-233 286

Abstract: These monthly reports trace the progress of the Solvent Refined Coal (SRC) process developed by the Pittsburgh and Midway Coal Mining Co. under contract to the Office of Coal Research since 1966. The process will undergo testing in a pilot plant recently completed near Tacoma, Wash., at a cost of \$18 million. In the SRC process, coal is first dissolved under moderate hydrogen pressure in a heavy aromatic solvent derived from process. The resultant coal solution is filtered to remove ash and a small amount of insoluble organic material and fractionated to recover the solvent. The main product from the process is a heavy organic material called solvent refined coal. Smaller quantities of hydrocarbon gases and light distillate liquids are also produced.

NTIS PB-233 285/6

6.1.23

MECHANISM OF HYDROGEN TRANSFER TO COAL AND COAL EXTRACTS

G. P. Curran, R. T. Struck and E. Gorin (Consolidation Coal Co., Res. Div., Library, Pa.) Amer. Chem. Soc., Div. Fuel Chem., Preprints 10(2), C-130--C-148(1966)(Eng.).

Abstract: The kinetics of coal extn. and of the transfer of H₂ from Tetralin to bituminous coal and a "shallow" ext. derived from coal were examined. A number of other active H-donor solvents were also tested, such as cyclohexylphenol, cyclohexanol, dihydrophenanthrene, and isopropanol. All of the above donors gave about the same amt. of H-transfer at equal time and temp. conditions. A limiting value of the amt. of H₂ that could be transferred was approached at long treatment times. The depth of extn. was a function primarily of the amt. of H₂ transferred and relatively independent of the solvent compn. employed. The H-transfer results were interpreted in terms of a free-radical mechanism wherein the rate-detg. step is the rupture of covalent bonds. The exptl. data could be adequately represented by a model where bonds of 2 different strengths are involved. The dependence of H-transfer rate on Tetralin concn. was quite complex and could not readily be interpreted in terms of a simple theoretical model. A semi-empirical correlation is given which adequately represents the data.

6.1.24

SOLVATION OF COAL

Willard C. Bull, Lawrence G. Stevenson, Dean L. Kloepper and Thomas F. Rogers (to United States Dept. of the Interior). U.S. 3,341,447, Sept. 12, 1967, Apply. Jan. 18, 1967; 6pp.

Abstract: A process for upgrading of carbonaceous fuels by a soln. process into low-ash, low-O, and low-S fuels is described. Thus, Kentucky No. 11 coal was dissolved in a solvent recovered from previous extn. runs (b.150-750°, d. 1.1, C:H 1.0/0.9 to 1.0/0.3) at 1000 psi. (80% H), 410°, and solvent/coal ratio 3/1. The solvent/coal slurry was heated in 12-20 sec. to 410° until the viscosity rose and then dropped to 3.43. The properties of the product, after filtering, were 0.48% ash, 36.6% volatile matter, 220° m.p., d. 1.24 and 15,768 Btu./lb.

6.1.25
CHEMICAL ASPECTS OF INTERFUEL CONVERSION

Yen, T. F.
University Southern California, Los Angeles, Ca.
Energy Sources 1.1.FALL 1973
117-36
Symposium of New Sources of Energy
Los Angeles, Ca.
7 May 1973

6.1.26
REMOVAL OF SULFUR FROM COAL BY TREATMENT WITH HYDROGEN. Phase I. The Effect of Operating Variables and Raw Material Properties. Research and Development Report No. 77, Interim Report No. 1.
Gary, J. H., Baldwin, R. M., Bao, C. Y., Kirchner, J., Golden, J. O.
Colorado School of Mines, Golden (USA)
325 and 400° C at 600 and 1200 psig, respectively.
Contract 14-32-0001-1225
30 May 1973.

6.1.27
CENTRIFUGAL COAL FLASH HYDROGENATION IN A ROTATING FLUIDIZED BED REACTOR FOR A FULL SIZED COAL LIQUEFACTION PLANT

Sheehan, T. V., Steinberg, M., Lee, Q.
Brookhaven National Lab., Upton, N.Y.
Aug 73 34p
Monitor: 18

Abstract: A short contact time (5 sec), high-temperature (1000F), high pressure (68 atm) reaction of hydrogen with coal favors high conversions to liquid hydrocarbons. The rotating fluidized bed is uniquely suited for obtaining these process conditions. The centrifugal force in the rotating bed maintains the coal particles in position against the high velocity stream of fluidizing hydrogen. The gravitational degree of freedom in a rotating fluidized bed yields extremely high heat transfer and reaction rates. One rotating fluidized bed unit 5 ft. dia. x 2.5 high should be able to process 9,000 T/D of coal at 60% conversion efficiency for the production of the equivalent of 38,000 bbl/day of liquid hydro-carbon product. A design analysis of the centrifugal hydrogenation unit and the entire plant as well as a preliminary cost estimate is presented.

NTIS BNL-18268

6.1.28

DEVELOPMENTAL AND RATE STUDIES IN PROCESSING OF COAL MINERALS

Jensen, G. A.

Washington State Univ., Pullman, Wa. 1973

University Microfilms Order No. 74-4108.

6.1.29

CHEMICAL ASPECTS OF INTERFUEL CONVERSION

Yen, T. F.

Univ. of Southern California, Los Angeles

Source - Energy Sources v 1 n 1 Fall 1973 p 117-136

Abstract: For both gasification and liquefaction of raw fuels into end fuels, the chemical structure of various stages of conversion is of great importance. Variations in process design as well as variables of a given process can be correlated with the structural parameters of the fuels. Even within a given type of raw fuel, large differences occur. Optimization of the conversion process to the best end fuel should be considered (intrafuel optimization). Furthermore, it is advantageous to refine a combination of two types of raw fuels (interfuel combinations). Economics should always be related directly to the chemical structures of the raw fuels, whether to separation and extraction or to the environment. New in situ and biochemical recoveries should be sought. Further extension to the existing resources based on chemical knowledge could be explored.
11 refs.

6.1.30

SOLVENT REFINED COAL (SRC) PROCESS

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.

Monthly rept. nos. 80 thru 83, May-Aug 73.

Aug 73 307p

Contract: DI-14-01-0001-496

Monitor: 18

See also Monthly rept. nos. 75-79, PB-233 285 and Monthly rept. nos. 84-87, PB-233 287.

Abstract: These monthly reports trace the progress of the Solvent Refined Coal (SRC) process developed by the Pittsburg and Midway Coal Mining Co. under contract to the Office of Coal Research since 1966. The process will undergo testing in a pilot plant recently completed near Tacoma, Wash., at a cost of \$18 million. In the SRC process, coal is first dissolved under moderate hydrogen pressure in a heavy aromatic solvent derived from the process. The resultant coal solution is filtered to remove ash and a small amount of insoluble organic material and fractionated to recover the solvent. The main product from the process is a heavy organic material called solvent refined coal. Smaller quantities of hydrocarbon gases and light distillate liquids are also produced.

NTIS PB-233 286/4

6.1.31

CLEAN FUELS FROM COAL. Conference Held at Chicago, Illinois, September 10-14, 1973.

White, J. W., Larson, M., (Eds.)

Institute of Gas Technology, Chicago 1973

6.1.32

SOLVENT REFINED COAL (SRC) PROCESS

Pittsburgh and Midway Coal Mining Co., Kansas City, Mo.

Monthly rept. nos. 84 thru 87, Sep-Dec 73.

Dec 73 245p

Contract: DI-14-01-0001-496

Monitor: 18

See also Monthly rept. nos. 80-83, PB-233 286 and Monthly rept. nos 88-90, PB-233 288.

Abstract: These monthly reports trace the progress of the Solvent Refined Coal (SRC) process developed by the Pittsburg and Midway Coal Mining Co. under contract to the Office of Coal Research since 1966. The process will undergo testing in a pilot plant recently completed near Tacoma, Wash., at a cost of \$18 million. In the SRC process, coal is first dissolved under moderate hydrogen pressure in a heavy aromatic solvent derived from the process. The resultant coal solution is filtered to remove ash and a small amount of insoluble organic material and fractionated to recover the solvent. The main product from the process is a heavy organic material called solvent refined coal. Smaller quantities of hydrocarbon gases and light distillate liquids are also produced.

NTIS PB-233 287/2

6.1.33

REMOVAL OF SULFUR FROM COAL BY TREATMENT WITH HYDROGEN

Gary, J. H., Baldwin, R. M., Bao, C. Y., Bain, R. L., Kirchner, M.S., Golden, J. O.

Colorado School of Mines, Golden

Am. Chem.Soc., Div. Fuel Chem. Prepr. 19/1/74
167-191

Abstract: This is a report on an experimental program which has been undertaken to determine the importance of operating variables and raw material properties upon desulfurization via the solvent refining process. This process is being studied in bench scale, high-pressure, high-temperature, rocking-bomb autoclave batch reactors. Initially five variables were studied -- temperature, partial pressure of hydrogen, solvent-to-coal ratio, solvent type, and reaction time. The reaction time was determined to be statistically unimportant -- anthracene was shown to be the better solvent.

American Chemical Society, Division Fuel Chemistry Meeting
Los Angeles Ca., USA
1 Apr 1974

6.1.34

DUAL TEMPERATURE COAL SOLVATION PROCESS

Department of the Interior, Washington, D.C. (109 950)

Patent Application

Bull, Willard E., Schmid, Bruce, Hinderliter, Charles H., Wright, Charles H., Pastor, Gerald R.

Filed 4 Mar 74 44 p

Rept. No.: PAT-APPL-446 971, DOCKET/OCR-2144

Monitor: 18

Government-owned invention for licensing. Copy of application available NTIS.

Abstract: The patent application describes a solvation process for producing deashed solid and liquid hydrocarbonaceous fuel from coal. Raw coal is slurried with a solvent comprising hydroaromatic compounds in contact with hydrogen in a first zone at a relatively high temperature to dissolve hydrocarbonaceous fuel from coal minerals by transfer of hydrogen from hydroaromatic solvent compounds to hydrocarbonaceous material in the coal. The solvent is then treated with hydrogen in a second zone at a lower temperature to replenish the solvent with hydrogen. Forced cooling of the slurry between zones accomplishes many significant improvements in the process.

NTIS PB-230 256/0

6.1.35

SOLVENT REFINED COAL PROCESS WITH ZONES OF INCREASING HYDROGEN PRESSURE

Department of the Interior, Washington, D.C. (109 950)

Patent Application

Author: Liebman, Israel, Corry, John, Richmond, Kenneth J.

Filed 4 Mar 74 50 p

Rept. No.: PAT-APPL-446 972, DOCKET/OCR-2143

Monitor: 18

Government-owned invention available for licensing. Copy of application available NTIS.

Abstract: The patent application describes a solvation process for producing deashed solid and liquid hydrocarbonaceous fuel from coal. Raw coal is slurried with a solvent comprising hydroaromatic compounds in contact with hydrogen in a first zone operating at a low residence time, a relatively high temperature and a relatively low hydrogen pressure to dissolve hydrocarbonaceous fuel from coal minerals by transfer of hydrogen from hydroaromatic solvent compounds to hydrocarbonaceous material in the coal. The solvent is then treated with hydrogen in a second zone at a longer residence time, a relatively low temperature and a relatively high hydrogen pressure to replenish the solvent with hydrogen.

NTIS PB-230 649/6

6.1.36

SOLVENT REFINED COAL PROCESS WITH RETENTION OF COAL MINERALS

Department of the Interior, Washington, D.C. (109 950)

Patent Application

Hinderliter, Charles R., Perrussel, Russell E.

Filed 4 Mar 74 33 p

Rept. No: PAT-APPL-446-974, Docket/OCR 2215

Monitor: 18

Government-owned invention available for licensing. Copy of application available NTIS.

Abstract: The patent application describes a solvation process for producing deashed solid and liquid hydrocarbonaceous fuel from coal. Raw coal is slurried with a solvent comprising hydroaromatic compounds in contact with hydrogen in a first zone to dissolve hydrocarbonaceous fuel from coal minerals by transfer of hydrogen from hydroaromatic solvent compounds to hydrocarbonaceous material in the coal. The slurry is then treated with hydrogen in a second zone to replenish the solvent with hydrogen. The process is improved by retention of coal minerals in the second zone.

NTIS PB-230 255/2

6.1.37

SOLVENT REFINED COAL PROCESS INCLUDING RECYCLE OF COAL MINERALS

Department of the Interior, Washington, D.C. (109 950)

Patent Application

Shora, Frank C. Jr., Tarman, Paul B

Filed 4 Mar 74 34 p

Rept No: PAT-APPL-466 973, Docket/OCR-2145

Monitor: 18

Government-owned invention available for licensing. Copy of application available NTIS.

Abstract: The patent application describes a solvation process for producing deashed solid and liquid hydrocarbonaceous fuel from coal. Raw coal is slurried with a solvent comprising hydroaromatic compounds in contact with hydrogen in a first zone to dissolve hydrocarbonaceous fuel from coal minerals by transfer of hydrogen from hydroaromatic solvent compounds to hydrocarbonaceous material in the coal. The solvent is then treated with hydrogen in a second zone to replenish the solvent with hydrogen. Hydroaromatic solvent and residue coal minerals are recycled to the first zone.

NTIS PB-230 650/4

6.1.38
SOLVENT REFINED COAL (SRC) PROCESS

Pittsburgh and Midway Coal Mining Co., Kansas City, Mo.

Monthly rept. nos. 88 thru 90, Jan-Mar 74.
Mar 74 164p
Contract: DI-14-01-0001-496
Monitor: 18
See also Monthly rept. nos. 84-87, PB-233 287.

Abstract: These monthly reports trace the progress of the Solvent Refined Coal (SRC) process developed by the Pittsburgh and Midway Coal Mining Co. under contract to the Office of Coal Research since 1966. The process will undergo testing in a pilot plant recently completed near Tacoma, Wash. at a cost of \$ 18 million. In the SRC process, coal is first dissolved under moderate hydrogen pressure in a heavy aromatic solvent derived from the process. The resultant coal solution is filtered to remove ash and a small amount of insoluble organic material and fractionated to recover the solvent. The main product from the process is a heavy organic material called solvent refined coal. Smaller quantities of hydrocarbon gases and light distillate liquids are also produced.

NTIS PB-233 288/0

6.1.39
SOLVENT REFINED COAL PROCESS WITH ZONES OF INCREASING HYDROGEN PRESSURE

Department of the Interior, Washington, D.C., (109 950)

Patent
Wright, Charles H., Pastor, Gerald R.
Filed 4 May 74, patented 20 May 75 16 p
Rept No. PAT-APPL-446 972, PATENT-3 884 795
Monitor: 18
Also includes report no. DOCKET/OCR-2143
Government-owned invention available for licensing. Copy of patent available
Commissioner of Patents, Washington, D.C. 20231

Abstract: This invention relates to a non-catalytic liquid solvent dissolving process for producing reduced or low ash hydrocarbonaceous solid fuel and hydrocarbonaceous distillate liquid fuel, from ash-containing raw coal.

NTIS PB-246 010/35T

6.1.40

REMOVAL OF SULFUR FROM COAL BY TREATMENT WITH HYDROGEN. Phase I: The Effect of Operating Variables and Raw Material Properties

Colorado School of Mines, Golden. Dept. of Chemical and Petroleum Refining Engineering.

*Office of Coal Research, Washington, D.C.

Interim rept. no. 1, May 72-may 73

Gary, James H., Baldwin, R. M., Bao, C. Y., Kirchner, M., Golden, J. O.

May 74 110p

Contract:DI-14-32-0001-1225

Monitor: OCR-77-INT-1

Abstract: A review is presented by experiments conducted to determine whether reaction temperature, pressure, reaction time, solvent type, and solvent to coal ratio have a significant effect on the desulfurization of coal by hydrogen treatment. The process consisted of reacting a coal-solvent slurry with hydrogen at elevated temperatures and pressures in a batch autoclave rocking bomb reactor. Vacuum distillation was used to recover the solvent resulting in a solid low-sulfur removal and the removal of the forms of sulfur (organic, pyritic and sulfate) in the coal samples.

NTIS PB-235 849/7SL

6.1.41

SOLVENT REFINED COAL PROCESS INCLUDING RECYCLE OF COAL MINERALS

Department of the Interior, Washington, D.C. (109 950)

Patent

Bull, Willard C., Wright, Charles H., Pastor, Gerald R.

Filed 4 Mar 74, patented 20 May 75 12p

Rept No: PAT-APPL-446 973, PATENT-3 884 794

Monitor: 18

Government-owned invention available for licensing. Copy of patent available Commissioner of Patents, Washington, D.C. 20231

Abstract: This invention relates to a liquid solvent dissolving process for producing reduced or low ash hydrocarbonaceous solid fuel and hydrocarbonaceous distillate liquid fuel from ash-containing raw coal. The purpose of the invention is to avoid thermal hydrocracking as much as possible and at least to the extent of avoiding excessive production of hydrocarbon gases since production of gases diminishes the yield of desired deashed solid fuel and liquid fuel products. This purpose is accomplished by performing the solvation process in two separate stages, each stage preferably employing a different temperature.

NTIS PB-246 032/7ST

6.1.42

SOLVENT REFINED COAL PROCESS WITH RETENTION OF COAL MINERALS

Department of the Interior, Washington, D.C.

Patent

Author: Hinderliter, Charles R., Perrussel, Russell E.

Filed 4 Mar 74, patented 20 May 75 12p

Rept No. PAT-APPL-446 974, PATENT-3 884 796

Monitor: 18

Also includes report no. DOCKET/OCR-2215

Government-owned invention available for licensing. Copy of patent available Commissioner of Patents, Washington, D.C. 20231

Abstract: This patent involves a solvation process for producing deashed solid and liquid hydrocarbonaceous fuel from coal. Raw coal is slurried with a solvent comprising hydroaromatic compounds in contact with hydrogen in a first zone to dissolve hydrocarbonaceous fuel from coal minerals by transfer of hydrogen from hydroaromatic solvent compounds to hydrocarbonaceous material in the coal. The slurry is then treated with hydrogen in a second zone to replenish the solvent with hydrogen. The process is improved by retention of coal minerals in the second zone.

NTIS PB-246 009/5ST

6.1.43

DEPENDENCE OF COAL LIQUEFACTION BEHAVIOR ON COAL CHARACTERISTICS

Pennsylvania State Univ., University Park Coll. of Earth and Mineral Sciences.

14 Jun 74 43 p

Contract: 14-01-0001-390

Monitor: 18

NTIS OCR-61 INT-9

6.1.44

SOLVENT REFINED COAL PROJECT, PROGRESS REPORTS, APRIL-JUNE 1974

Pittsburgh and Midway Coal Mining Co., Merriam, Kans.

1974 126p

Monitor: 18

Abstract: Activities of the Pittsburg and Midway Coal Mining Co. (P and M) on the Solvent Refined Coal (SRC) Project during the period April 1, 1974, through June 30, 1974, are described. These activities include: construction and operation of the SRC Pilot Plant at Ft. Lewis, Wash.; laboratory research performed by P & M at Merriam, Kansas, to support the pilot plant operations; supporting research done by others under subcontract to P&M to study certain features of the SRC process. The detailed activities are given in the body of the report following an introduction describing the background history of the project.

NTIS FE-496-T-3

6.1.45

SOLVENT REFINED COAL STUDIES

Auburn Univ., Ala. Engineering Experiment Station.

*National Science Foundation, Washington, D.C. Research Applied to National Needs. (402 958)

Progress rept. 1 Oct 73-31 May 74.
25 Jun 74 108p

Grant: NSF-GI-38701

Monitor: NSF/RA/N-74-075

Abstract: This report discusses (1) experimental results and (2) model studies of solvent refining of coal. Section 1 summarizes the experimental apparatus, procedures, analyses and results obtained to date. Included in the "Experimental Results" are these topics: analysis of coal dissolution products; solvent characterization; hydrogenation apparatus, gas and liquid sampling, and analyses; preliminary results of autoclave runs, heat affects in coal dissolution - hydrogenation; effect of coal mineral matter upon coal conversion rate; rotating disc experiments; and the continuous reactor. The second section, "Model Studies," discusses (A) heat and mass transfer effects in solvent refining of coal - some theoretical aspects and preliminary mathematical model; and (B) theoretical investigation of coal structure and solubility.

NTIS PB-238 532/6ST

6.1.46

COAL AND COAL DERIVATIVES

Seitzer, Walter H; Shinn, Robert W.

Sun Research and Development Co.

U. S. 3,819,505, 25 June 1974. Appl. 181,229.

16 Sep. 1971; 3 pp.

Abstract: The invention comprises the process of dissolving subbituminous coal in a pressure reactor by heating a slurry of the coal in a solvent of anthracene oil hydrogenated to contain ~7-9% H₂ in the presence of H₂, CO and steam, at ~400° and ~2000-5000 PSIG. After use of the hydrogenated anthracene oil in the process it must be rehydrogenated in order to be used in a recycle. If the steam, CO and H₂ are added as separate entities, steam is placed in the reactor and after closing it, it is pressured with CO and H₂.

6.1.47

SYNTHETIC OIL FROM COAL

Kentucky Univ., Lexington. Dept. of Chemical Engineering.

*National Science Foundation, Washington, D.C. Research Applied to National Needs.

Biannual rept. no. 1, 1 Oct 73-31 Mar 74

Kermode, Richard L.

Jul 74 62p

Rept. No: UKY-TR86-74-CME2

Monitor: 18

Report on NSF/RANN project.

Abstract: A report of progress and accomplishments for the first six month period is presented on the study of liquefaction of coal by hydrogenation. Projects being studies include: a systematic study of variables associated with hydrogen production to identify those areas in which technical success is most likely to improve the overall economics of coal liquefaction; A solids separation study of flotation as a means of removing unconverted coal and ash from coal liquids; a low temperature carbonization process as a source for suitable refinery feedstock and char feedstock for a hydrogen plant; a systematic laboratory investigation to identify trace elements and minerals detrimental to catalytic hydrogenation of coal.

NTIS PB-234 460/4

6.1.48

THE RELATION OF COAL CHARACTERISTICS TO COAL LIQUEFACTION BEHAVIOR

Pennsylvania State Univ., University Park., Dept. of Geosciences

National Science Foundation, Washington, D.C.

Research applied to National Needs

Rept. No. 2

Given, P. H., Spackman, W., Davis, A., Walker, P. L. Jr., Lovell, H. L.

8 Aug 74 98p

Grant: NSF-GI-38974

Monitor: NSF/RA/N-74-154

Abstract: In this project various factors of coal (such as rank, petrographic composition, geological history and composition of the inorganic constituents) are studied systematically to determine their relevancy to liquefaction behavior of coals and the character of the products. A continuous flow reactor, batch autoclaves, low pressure reaction vessels and other equipment are used in this investigation. This report is organized under these topics: Introduction; Sample collection and characterization; Liquefaction behavior of a series of Appalachian coals; Major, minor and trace elements in liquid products and solid residues from catalytic hydrogenation of some coals; Mechanistic studies; Studies with the hydrogen transfer technique; The use of differential scanning calorimetry for evaluating coals for liquefaction studies; Characterization of mineral matter in coals by scanning electron microscope; and preparation of maceral concentrations for liquefaction research.

NTIS PB-239 261/1ST

6.1.49

TECHNICAL EVALUATION SERVICES, CLEAN LIQUID AND/OR SOLID FUELS FROM COAL.

Interim Technical Progress Report for the Period October 1972--August 1974.

Parsons (Ralph M.) Co., Pasadena, Calif

Aug 74 9p

Contract: 14-32-0001-1234

Monitor: 18

Abstract: No abstract available.

NTIS OCR-82

6.1.50

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL.
Volume II. Laboratory Studies, Part 1, Autoclave Experiments

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.
Office of Coal Research, Washington, D. C.

Interim rept. no. 6

Wright, Charles H., Perrussel, Russell E., Pastor, Gerald R.

Oct 74 335p

Contract: DI-14-01-0001-496

Monitor: OCR-53-INT-6

Abstract: This report is a summary of the autoclave experiments and related laboratory studies done in support of the development of the pilot plant for preparation of solvent refined coal. These studies were done to obtain data for use in planning the pilot plant construction and operations to assist in evaluating the commercial and economic feasibility of the Solvent Refined Coal Process. A considerable part of the work was devoted to evaluating various coals, solvents, and reducing gases that might be considered for further study in the pilot plant.

NTIS PB-236 305/9ST

6.1.51

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL.
Volume IV. Product Studies. Part 5, Developmental and Rate Studies in Processing of Coal Minerals

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.
Office of Coal Research, Washington, D.C.
Washington State Univ., Pullman, College of Engineering Research Div.

Interim Rept. No. 13

Nov 74 139p

Contract: DI-14-01-0001-496

Monitor: OCR-53-INT-13

See also PB-237 763. Prepared in cooperation with Washington State Univ., Pull. College of Engineering Research Div.

Abstract: Processing of coal minerals from the Solvent Refined Coal (SRC) Process is discussed. The report reviews the chemical reactions and kinetics of carbon gasification for the production of fuel as synthesis gas and subsequent recovery of elemental iron and sulfur.

NTIS PB-237 766/1ST

6.1.81

COAL TECHNOLOGY PROGRAM QUARTERLY PROGRESS REPORT FOR THE PERIOD ENDING
SEPTEMBER 30, 1975

Oak Ridge National Lab., Tenn.

Dec 75 69 p

Contract: W-7405-eng-26

Monitor: 18

Abstract: In hydrocarbon research the effort in experimental development focused upon modification of the atmospheric pressure reactor and successful completion of the first two runs using H_2 as the fluidizing gas. Effort was focused on installation and initial shakedown testing of the bench-scale hydrocarbonization system that is designed to process coal at a nominal rate of 10 lb/hr at pressures up to 300 psig and temperatures up to 1200°F. In solid-liquids separation work, solvent agglomeration-fractionation (SAF), followed by settling at elevated temperatures and pressures, continues to show promise as a solids separation scheme for Solvent Refined Coal (SRC) and similar processes. A preliminary economic evaluation of SAF, followed by settling and filtration of the bottoms material, shows a significant cost advantage over conventional rotary drum filtration. In the engineering evaluations of nuclear process heat for coal conversion, a preliminary study of the energy intensiveness and unit costs of various energy transportation modes was completed. A pressurized gasifier was selected and process flowsheets and material balances for the gasifier and gas-treating section were prepared for Synthoil. Research in the biomedical and environmental program continues.

NTIS ORNL-5093

6.1.52

TECHNOLOGY AND USE OF LIGNITE

Bureau of Mines, Grand Forks, N.Dak. Grand Forks Energy Research Labs.

Information circular

Gronhovd, Gordon H., Kube, Wayne R.

Nov 74 272p

Rept No: IC-8650

Monitor: 18

Proceedings of Bureau of Mines - University of North Dakota

Symposium Held at Grand Forks, N.Dak., on 9-10 May 1973.

Abstract: The proceedings of the 1973 Lignite Symposium held at Grand Forks, N.Dak., May 9-10, includes 16 papers: Operations of Western Company; New Developments in Open Cast Mining Technology at Rheinische Braunkohlenwerke, AG, Koeln; Big Stone Plant: Design Features and Fuel Handling; Shipment, Storage, and Handling Characteristics of Dried Low-Rank Coals; Gas from Coal: Fuel of the Future; Some Studies on Stack Emissions from Lignite-Fired Power Plants; Pilot Plant Scrubber Tests to Remove SO₂ Using the Soluble Alkali in Western Coal Fly Ash; Experience in Use of Brown Coals from the Latrobe Valley, Australia; Design Considerations for 575 MW Units at Big Brown Steam Electric Station; Design and Operating Experiences of Steam Generators for Low-Grade Brown Coal; New Day Dawns for Great Plains Coals; Utilization of Lignite and Subbituminous Ash; Low-Btu Fuel Gas for Power Generation; CO₂ Acceptor Process: Status of Development; Laboratory Studies on Solution-Hydrogenation of Lignite; and The Liquefaction of Subbituminous Coal.

NTIS PB-238 666/2ST

6.1.53

REMOVAL OF SULFUR FROM COAL BY TREATMENT WITH HYDROGEN

Gary, J. H. (Colorado School of Mines, Golden) Baldwin, R. M., Bao, C. Y., Bain, R. L., Kirchner, M.S., Golden, J. O.

Energy Sources, 2/1/1975

33-51

6.1.54

COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR JANUARY 1975

Oak Ridge National Lab., Tenn

Feb 75 51 p

ABSTRACT: No abstract available

NTIS ORNL-TM-4850

6.1.55

DEPENDENCE OF COAL LIQUEFACTION BEHAVIOR ON COAL CHARACTERISTICS

Pennsylvania State Univ., University Park. Coal Research Section.
Office of Coal Research, Washington, D.C.

Interim rept. Jan 73-June 74

Jan 75 45p

CONTRACT: DI-14-01-0001-390

Monitor: OCR-61-INT-9

Abstract: Liquefaction behaviour of coal samples was studied. The samples had widely differing sulfur contents (up to 6%) but the oils produced had sulfur contents less than 0.5% in almost all cases. In addition, the results strongly indicated that in a number of cases the mineral constituents of coals, usually considered as unwanted impurities, may actually have a beneficial effect as additional catalysts for the liquefaction process.

NTIS PB-238 522/7ST

6.1.56

CHEMICALS FROM COAL: MONTHLY PROGRESS REPORTS FOR THE PERIOD APRIL 15, 1974--
JANUARY 15, 1975

Dow Chemical Co., Midland, Michigan

Author: Peters, B. C.

1975 32 p

Contract: 14-32-0001-1534

Monitor: 18

Abstract: Laboratory studies in metal reactors aided by computer simulations are expected to provide comparative data from which preliminary capital requirements and operating costs can be estimated for a commercial plant that would use coal liquefaction products for the production of useful aliphatic and aromatic compounds. Initial results of fractionation of coal-derived oils by distillation and of hydrocracking a few of the distillate fractions are reported.

NTIS FE-1534-T-1

6.1.57

COAL TECHNOLOGY PROGRAM QUARTERLY PROGRESS REPORT NO. 1 FOR THE PERIOD ENDING
DECEMBER 31, 1974

Oak Ridge National Lab., Tenn

Apr. 75 103 p

Abstract: No abstract available.

NTIS ORNL -5026

6.1.58

SOLVENT REFINED COAL PROCESS

Baldwin, R. M. (Colorado School of Mines, Golden) Golden, J. O., Gary, J. H.,
Bain, R. L., Long, R. J.

Chemical Engineering Progress 71.4 April 1975

pp. 70-71

Abstract. The influence on the degree of desulfurization of the operating variables and raw-material properties and the desulfurization of coal char via the solvent-refined coal (SRC) about 1/3 of the S in the char. Increased S removal was favored by a combination of anthracene oil solvent pressure of 2000 psi temp. of 425° and a solvent to char ratio of 5:1 and the bulk of the S was removed from org. S forms. The residual S content decreased monotonically with increasing temp.: 1% C₁-C₄ hydrocarbons, and 1% H₂S were present in the product gas in addition to the H₂ and CO₂.

6.1.59

RECYCLING SOLVENT TECHNIQUES FOR THE SRC (SOLVENT REFINED COAL) PROCESS

Anderson, R. P.

Pittsburg and Midway Coal Mining Co., Merriam, Kansas

Chemical Engineering Progress 71.4 April 1975

pp 72-74

Abstract: SRC startup with a petroleum-derived oil and recycle of solvent until a steady state recycle solvent compn. was achieved are discussed. There was an increase in aromaticity and a corresponding decrease in the aliphatic H₂ in the startup solvent compn. The final solvent contained aliphatic chains and was less aromatic and less reactive in the SRC process than anthracene oil. Recycle solvent was satisfactory and was obtained in break-even yield.

6.1.60

COAL DESULFURIZATION IN THE P AND M SOLVENT REFINING PROCESS

Anderson, R. P., Wright, C. H.

Pittsburg and Midway Coal Mining Co., Merriam, Kansas

Use of 2 dissolver vessels. S levels as low as 0.52 percent obtained.

American Chemical Society - Washington, D.C.; 1975

Symposium on Low-sulfur Liquid Fuels from Coal.

169. National Meeting of the American Chemical Society

Philadelphia, Pa.

6 April 1975

6.1.61

PHOTOMICROGRAPHIC STUDY OF COAL DISSOLUTION

Guin, J. A., Tarrer, A. R., Taylor, Z. L., Green, S. C.

Auburn University, Alabama

American Chemical Society, Washington, D.C. - 1975

Symposium on Low-Sulfur Liquid Fuels from Coal

169. National Meeting of the American Chemical Society

Philadelphia, Pa. 6 April 1975

Abstract: Coal slurried with solvent in presence of hydrogen at 375-425°C and filtered gives solvent refined coal that is low in ash and sulfur after distillation of solvent.

6.1.62

COAL TECHNOLOGY PROGRAM QUARTERLY PROGRESS REPORT NO. 1 FOR THE PERIOD ENDING DECEMBER 31, 1974

Oak Ridge National Lab., Tenn.

Apr 75 103p

Contract: W-7405-eng-26

Monitor: 18

Abstract: No abstract available

NTIS ORNL-5026

6.1.63

COAL CONVERSION PROCESSES. PART I. LIQUEFACTION. R AND D REPORT NO. 66. INTERIM REPORT NO. 4, AUGUST 1973-AUGUST 1974

West Virginia University, Morgantown Dept. of Chemical Engineering

Wen, C. Y., Henry, J. D., Patel, B. S., Han, B. K., McMichael, W. J.

April /5 67 p

Rept. No. OCR-66-INT4

Contract: E(49-18)-479

Monitor 18

Abstract: Available experimental data on the dissolution of coal into solvent-hydrogen mixtures were analyzed to obtain a mathematical expression for the rate of dissolution. The rate of dissolution was found to depend exponentially on
(Cont'd)

the hydrogen partial pressure and was proportional to the amount of undissolved organic material per unit volume of slurry. The rate was found also to depend on the type of reactor and coal. The low activation energy for coal dissolution appears to indicate that the dissolution may be controlled by the diffusion of some species in the solution phase. The removal of ash from coal-derived liquids by filtration and centrifugation was examined and the economics of the separation has been analyzed in detail for the COED, SRC, and Synthoil processes. In the SRC process the ash separation represented a major portion of the overall fixed capital investment ranging from 23 to 50% for the SRC process.

NTIS FE-0479-3

6.1.64

SOLVENT REFINED COAL PROCESS WITH ZONES OF INCREASING HYDROGEN PRESSURE

Department of the Interior, Washington, D.C.

Author: Wright, Charles H., Pastor, General R

Patent

Filed 4 May 74, Patented 20 May 75 16p

Report No. PAT-APPL-446 972, Patent 3 884 795

Monitor: 18

Also includes Report No. Docket/OCR-2143

Government-owned invention available for licensing. Copy of Patent available
Commissioner of Patents, Washington D.C., 20231

6.1.65

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL.
Volume II. Laboratory Studies. Part 3. Continuous Reactor Experiments Using
Petroleum Derived Solvents. Period Covered - January 1973--June 1974.

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.

Anderson, R. P., Wright, C. H.

May 75 192p

Rept No: OCR-53-INT-8

Contract: E(49-18)-496

Monitor: 18

Abstract: Continuous reactor experiments and related laboratory studies, completed January 1973 through June 1974, supporting development of the Tacoma, (Fort Lewis) pilot plant for preparation of Solvent Refined Coal are summarized. These studies were done to evaluate the solution of coals in petroleum-derived solvents, to recycle solvent until a steady state composition was obtained, and to define startup conditions for the pilot plant. The results have been correlated with results from previous work with coal-derived solvents.

NTIS FE-496-T1

6.1.66

PROCESS DATA FOR COAL LIQUEFACTION PROCESSES. PART I

Oak Ridge National Laboratory, Tenn. (4832000)

Author: Lantz, P. M.

May 75 150p

Contract: W-7405-eng-26

Monitor: 18

Abstract: Process data for five coal liquefaction processes are presented in a semi-handbook form, representing information currently available in the open literature. This report represents a digest of the processes for quick reference.

NTIS ORNL-TM-4789 (Pt. 1)

6.1.67

SOLVENT REFINING OF ILLINOIS NO. 6 and PITTSBURGH NO. 8 COALS

Hydrocarbon Research, Inc., Trenton, N. J.

*Electric Power Research Inst., Palo Alto, Calif.

Final report

Author: Johanson, Edwin

June 75 90p

Monitor: EPRI-RP389-FR-Vol. 1

Abstract: This report discusses three continuous bench unit runs that provided results of the effect of backmixing in the contactor during SRC operations. The test program was carried out in a continuous bench-scale pilot unit. The simulation of backmixing was achieved by recycling unmodified hot reactor slurry directly from the reactor outlet to the reactor inlet without depressurizing the stream. The amount of internal recycle ranged from 17 to 25 times the feed slurry.

NTIS PB-243 875/2ST

6.1.68

PROJECT LIGNITE: PREMIUM FUELS FROM NORTHERN GREAT PLAINS LIGNITE. PROCESS DEVELOPMENT FOR SOLVENT REFINED LIGNITE. DESIGN OF CONTINUOUS 50 POUNDS PER HOUR PDU. R AND D REPORT NO. 106, INTERIM REPORT NO. 1.

March 1972--September 1974

North Dakota Univ., Grand Forks Engineering Experiment Station

June 1975 48p

Contract: 14-32-0001-1224

Monitor: 18

Abstract: The University of North Dakota Engineering Experiment Station contracted to undertake a broad research program aimed at producing premium fuels from lignite. The initial project under the program was to conduct
(Cont'd)

bench scale autoclave experimentation and to design, construct and operate a Process Development Unit (PDU) for demonstration and development of a process for producing low-ash, low-moisture, high-heating-value fuel from lignite. The PDU was designed by process engineers on the Project Lignite staff and is intended to be the first step in this broad effort to produce upgraded fuel materials from lignite. This report describes details of design and proposed operation of all sections of the PDU, together with discussions relating to anticipated mechanical and process problems and their proposed solutions. The Process Development Unit has a nominal design capacity of 50 pounds of raw lignite feed per hour.

NTIS FE-1224-T-1

6.1.69

CHEMICALS FROM COAL. MONTHLY PROGRESS REPORTS FOR THE PERIOD JANUARY-JUNE 1975

Dow Chemical Co., Midland, Mich.

Author: Peters, B. C.

1975 75p

Contract: E(49-18)-1534

Monitor: 18

Abstract: Laboratory studies in metal reactors aided by computer simulations are expected to provide comparative data from which preliminary capital requirements and operating costs can be estimated for a commercial plant which would use coal liquefaction products for the production of useful aliphatic and aromatic compounds. A straight run distillation of H-coal oil and another hydrocracking run of a COED Syncrude fraction are reported. Trace metal analyses are given for COED Syncrude fractions. In-house analytical techniques were refined and will be included in various data compilations being prepared.

NTIS FE-1534-T-2

6.1.70

DUAL TEMPERATURE COAL SOLVATION PROCESS

Department of the Interior, Washington, D.C.

Patent

Author: Wright, Charles H., Pastor, Gerald R.

Filed 4 Mar 74, patented 1 Jul 75 16p

Rept No: PAT-APPL-446 971, PATENT-3 892 654

Monitor: 18

Also includes report no. DOCKET/OCR-2144

Government-owned invention available for licensing. Copy of patent available Commissioner of Patents, Washington, D.C. 20231

Abstract: The invention involves a solvation process for producing deashed solid and liquid hydrocarbonaceous fuel from coal. Raw coal is slurried with a solvent comprising hydroaromatic compounds in contact with hydrogen in a first zone at a relatively high temperature to dissolve hydrocarbonaceous

(Cont'd)

fuel from coal minerals by transfer of hydrogen from hydroaromatic solvent compounds to hydrocarbonaceous material in the coal. The solvent is then treated with hydrogen in a second zone at a lower temperature to replenish the solvent with hydrogen. Forced cooling of the slurry between zones accomplishes many significant improvements in the process.

NTIS PB-246 070/7ST

6.1.71

CHEMICALS FROM COAL. QUARTERLY PROGRESS REPORTS FOR THE PERIOD JANUARY-JUNE 1975.

Dow Chemical Co., Midland, Mich. (2196000)

Author: Peters, B. C.

1975 41p

Contract: E(49-18)-1534

Monitor: 18

Abstract: Laboratory studies in metal reactors aided by computer simulations are expected to provide comparative data from which preliminary capital requirements and operating costs can be estimated for a commercial plant which would use coal liquefaction products for the production of useful aliphatic and aromatic compounds. A sample of USBM Synthoil coal oil was obtained. Petrochemical processing experiments and data interpretation continued on FMC COED Syncrude and HRI H-Coal Oil. The COED Syncrude straight run mid-distillate was submitted to catalytic hydrocracking and steam coil cracking. The hydrocrackate was further hydrocracked and steam coil cracked. Trace metal analyses were reported for the straight run products. Initial straight run distillations of the H-Coal oil were completed along with steam coil cracking of the straight run naphtha. Hydrocracking of the straight run mid-distillate and further hydrocracking of the resulting hydrocrackate were completed, and considerable attention was given to improving in-house sulfur and nitrogen analytical techniques. COED Syncrude hydrocracking results were interpreted and experimental hydroprocessing of H-Coal Oil and Synthoil was conducted.

NTIS FE-1534-T-4

6.1.72

CONVERSION OF COAL TO OILS AND CHEMICALS

Krishna Murthy, V. A.

Central Fuel Research Inst., India

J. Mines, Met. Fuels, 23. 6 June 1975

pp 286-292

Abstract: The following processes of coal conversion to oils and chemicals are reviewed: (1) hydrogenation of coal, (2) solvent extraction of coal, (3) hydrogenation of tar obtained from pyrolysis of carbonization of coal,
(Cont'd)

and (4) Fischer-Tropsch process -- coal gasification followed by synthesis of oils and chemicals. The cost consideration and economics of these processes are also examined.

6.1.73

PROJECT LIGNITE QUARTERLY TECHNICAL PROGRESS REPORT NO. 3. October-December, 1974

North Dakota University, Grand Forks. (4746800)

Severson, D. E.

15 July 75 26p

Contract: E(49-18)-1224

Monitor: 18

Abstract: Tests in which lignite was dried in the batch autoclave with solvent indicated that there was no generation of solvent-type material. In fact, appreciable solvent was retained by the lignite and there was no reduction in S content. First and second pass tests in the solvent-recycle series using FS-120 as initial solvent to produce coal-derived solvent indicated no appreciable degradation of solvent or reduction in liquefaction. Variation in heating rates between autoclaves under otherwise similar experimental conditions apparently resulted in some differences in liquefaction characteristics. Hydrogenation of Solvent-Refined Lignite (SRL) in University Supporting Research work indicated that the highest yields of gases and distillable products were obtained at solvent: SRL ratio of 1:1. Higher or lower ratios gave lower conversions. Low solvent: SRL ratios with tetralin as solvent increased concentrations of aromatics in hydrogenation products. Conversions in hydrogenations with FS-120 as solvent were nearly as high as with tetralin. Ni-Mo-Al₂O₃ was shown to be a superior hydrogenation catalyst in comparison with Ni-W-SiO₂-Al₂O₃. Fast fluidization of -100 mesh catalyst particles was achieved at air velocities of 4.33 to 7.48 ft/sec at feed rates to 5 lb/hr giving bed densities as high as 15 lb/cu ft. Air velocities of 9.77 ft/sec were required for fast fluidization of sand particles. At slightly higher velocities, unstable conditions occurred with the experimental equipment used.

NTIS FE-1224-41

6.1.74

COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR APRIL 1975

Oak Ridge National Lab., Tenn

Jul 75 66p

Abstract: This report, the ninth of a series, is a compendium of monthly progress reports for the ORNL research and development projects that are in support of the increased utilization of coal as a source of clean energy.

(Cont'd)

The projects reported this month include those for hydrocarbonization, solid-liquid separations, in situ gasification, chemical research and development, analytical chemistry coal-fueled MIUS, biomedical and environmental, engineering and economic evaluations, engineering evaluations of nuclear process heat for coal conversion, and systems studies of coal production.

NTIS ORNL-TM-4946

6.1.75

COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR OCTOBER 1974

Oak Ridge National Lab., Tenn.

Author: Nichols, J. P.

Aug 75 25 p

Contract: W-7405-eng-26

Monitor: 18

Abstract: Monthly progress reports are compiled for the ORNL research and development projects directed toward the increased utilization of coal as a clean source of energy. The currently funded projects (and their sponsors) are those for: (1) Chemical research on molten salt methanation catalysts (AEC-DAT), (2) Characterization of coal conversion process streams (AEC-DAT), (3) Removal of heteroatoms from coal (AEC-DPR), (4) Bench-scale development of synthesis gas treatment (AEC-DAT), (5) Experimental engineering in separations technology (OCR), (6) Bench-scale development of a hydrocarbonization process (OCR), (7) Studies of a coal-fired modular integrated utility system (HUD and OCR), and (8) Studies of the environmental aspects of trace contaminants from coal conversion processes (NSF-RANN). Both the $AlCl_3$ -NaCl melt and the metal wall of the reaction vessel were important in promoting the hydrogenation of CO. Chromatographic studies indicated a large number of types of organosulfur compounds in samples of oil product from a coal conversion pilot plant. Thermodynamic studies were made in preparation for initial experiments of the hydrogenolysis of model compounds using commercial catalysts; and design studies in preparation for experimental engineering work in hydrogenation, solid-liquid separations, gas purification, and fluidized-bed combustion.

NTIS ORNL-TM-5046

6.1.76

COAL TECHNOLOGY PROGRAM QUARTERLY PROGRESS REPORT NO. 2 FOR THE PERIOD ENDING MARCH 31, 1975

Oak Ridge National Laboratory, Tennessee

Aug 75 71p

Contract: W-7405-eng-26

Monitor: 18

NTIS ORNL-5049

6.1.77

PROJECT LIGNITE QUARTERLY TECHNICAL PROGRESS REPORT NO. 4, JANUARY, FEBRUARY AND MARCH 1975

North Dakota University, Grand Forks.

Severson, E.

26 August 1975 28p

Contract: E(49-18)-1224

Monitor: 18

Abstract: Two 8-hour shakedown runs were made with the Process Development Unit (PDU) to determine operability of equipment and to train operators. Test included circulating first a lube oil-fuel oil mixture, and then FS120 solvent plus nitrogen. No solid was fed to the process. Several problem areas with equipment and instrumentation were discovered and are being corrected. Construction activities were concentrated in the solids-liquid separation and SRL hydrogenation areas. Most other areas are now operational. Recycle of recovered solvent, starting initially with FS120, through the batch-liquefaction processes has been completed for 5 cycles. No significant changes in conversion, product distribution or solvent characteristics were noted. It was indicated that sufficient solvent could be recovered to sustain the process in continuous operation. In catalytic hydrogenation of SRL, a relatively high conversion was realized without solvent. The aromatic contents of hydrogenated products increased with a decrease in solvent:SRL ratio while maximum conversion was obtained at a solvent:SRL ratio of 1:1. In related work, conventional boiling bed and "fast" fluidization of lignite, catalyst, and sand particles was achieved in bench-scale equipment. High slip-velocities of particles in fast fluidization approached that of the superficial air velocity indicating extensive back-mixing.

NTIS FE-1224-44

6.1.78

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL. Volume II. Laboratory Studies. Part 2. Continuous Reactor Experiments Using Anthracene Oil Solvent. R and D Report No. 53. Interim Report No. 7. Period Covered: October 1970-November 1972.

Pittsburg and Midway Coal Mining Co., Merriam, Kans.

Wright, C. H., Pastor, G. R., Perrussel, R. E.

Sept. 75 277p

Contract: E(49-18)-496

Monitor: 18

Abstract: A summary of the work done to develop a continuous laboratory reactor system to study solvent refining of coal is presented. A description is included of the evolution of the continuous reactor system and of the analytical methods developed to support the studies done. As a result of this work apparatus and operating procedures were devised that allowed accurate closure of material balances and of most elemental balances and of most elemental balances involved in the study of this process. Studies were done with a bituminous coal, a lignite coal, and a subbituminous coal, each chosen to represent a typical coal within the ranks represented. Pure hydrogen, carbon

(Cont'd)

monoxide, and carbon monoxide-hydrogen mixtures were considered as reducing gases for each coal. Raw anthracene oil and two different lots of partly hydrogenated anthracene oil were used as solvent in these studies.

NTIS FE-496-T4

6.1.79

COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR JULY 1975

Oak Ridge National Laboratory, Tenn.

Oct 75 51p

Contract: W-7405-eng-26

Monitor: 18

Abstract: This report, the twelfth of a series, is a compendium of monthly progress reports for the ORNL research and development projects that are in support of the increased utilization of coal as a source of clean energy. The projects reported this month include those for hydrocarbonization, solid-liquid separations, in-situ gasification, chemical research and development, analytical chemistry, coal-fueled conversion, and engineering evaluation of the Hydrocarbonization and Synthoil processes.

NTIS ORNL-TM-5037

6.1.80

COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR SEPTEMBER 1975

Oak Ridge National Laboratory, Tenn.

Oct 75 25p

Contract: W-7405-eng-26

Monitor: 18

Abstract: This report, the fourteenth of a series, is a compendium of monthly progress reports for the ORNL research and development projects that are in support of the increased utilization of coal as a source of clean energy. The projects reported this month include those for hydrocarbonization, solid-liquid separations, chemical research and development, analytical chemistry, engineering evaluations of nuclear process heat for coal conversion, coal-fueled MIUS, and engineering evaluations of the Hydrocarbonization and Synthoil processes.

NTIS ORNL-TM-5124

6.1.82

COAL TECHNOLOGY PROGRAM. ANNUAL INTERIM REPORT FOR FISCAL YEAR ENDING
JUNE 30, 1975

Oak Ridge National Laboratory, Tenn.

Oct 75 115p

Contract: W-7405-eng-26

Monitor: 18

Abstract: In hydrocarbonization research, the review and evaluation of existing process technology was completed. Experimental development work, using ambient mock-ups, has been conducted to evaluate the performance of a recirculating fluidized-bed reactor, a coal feeder, a flowmeter for coal, solids withdrawal, and cyclones. A review and evaluation of available data in solid-liquid separations was completed followed by scouting tests in agglomeration, settling, centrifugation, filtration, and solvent fractionation, settling, centrifugation, filtration, and solvent fractionation of SRC and COED unfiltered oils. Experimental simulation of the in-site gasification process was conducted. Pyrolysis experiments with maximum temperatures of 1000°C were performed with large instrumented blocks of subbituminous coal. It was concluded that volatilization of water is the heat-transfer-rate-limiting mechanism and that high-temperature pyrolysis reactions are decidedly exothermic. In the project for systems studies of coal production, hypothetical mine models are being constructed. Work continues in the engineering evaluations of the Synthoil and Hydrocarbonization processes. In the engineering evaluations of nuclear process, heat from coal conversion, United Engineers and Constructors, Inc. made a study of the use of very high-temperature nuclear reactors (VHTRs) for process heat applications. Some conclusions of the study are that the Hy-Gas process is less expensive for production of synthetic pipeline gas. The General Atomic/Stone and Webster (GA/S and W) process using nuclear heat is competitive to the Lurgi process. Depending on coal costs, GA/S and W may be competitive to the Koppers-Totzek plant.

NTIS ORNL-5069

6.1.83

PROJECT LIGNITE. QUARTERLY TECHNICAL PROGRESS REPORT NO. 5. APRIL, MAY AND JUNE 1975 AND ANNUAL SUMMARY, FISCAL YEAR 1975

North Dakota Univ., Grand Forks, Engineering Experiment Station.

Energy Research and Development Administration

Severson, D. E.

3 Dec 75 53p

Contract: E(49-18)-1224

Monitor: 18

Abstract: The continuous lignite liquefaction process development unit was operated in a shake-down mode without use of the solid-liquid separation section. The purposes of these preliminary tests were to train operators and to determine operability of equipment. Seven runs were initiated using lignite, solvent and synthesis gas. None of these was completed because of difficulties with equipment and operational problems. Modification of equipment and improvements in instrumentation and control units are continuing

(Cont'd)

as necessary to improve operability of the PDU. Tests continued using batch-autoclave experiments to study process conditions for liquefaction of lignite. Using a carbon black feedstock as starting solvent, five passes of recycled solvent through successive runs indicated no significant changes in solvent quality. Approximately 50 experiments were completed to evaluate process parameters for the conversion of solvent refined lignite (SRL) to light liquid fuels by catalytic hydrogenation in a one-liter autoclave. Catalysts are required for reasonable conversions of SRL. Highest conversions of SRL to gases and distillable products were obtained with a solvent to SRL ratio of 1:1. Ratios higher or lower gave reduced conversions. With reduced solvent (tetralin) concentration, concentration of aromatics in hydrogenation products increased linearly. A relatively high conversion of SRL was obtained by catalytic hydrogenation without solvent. Larger scale batch tests gave similar overall conversions although the yield of gaseous products increased while gasoline yield decreased. Hydrogenation of SRC (from bituminous coal) under similar test conditions gave conversions essentially the same as with SRL.

NTIS FE-1224-48

6.1.84

PROCESS LIGNITE. QUARTERLY TECHNICAL PROGRESS REPORT NO. 6. July-September 1975

North Dakota Univ., Grand Forks Engineering Experiment Station

Severson, D. E.

22 Dec 75 50p

Contract: E(49-18)-1224

Monitor: 18

Abstract: Progress is reported in developing data and know-how for the refinery processes involved in creating premium solid, liquid and gaseous fuels from lignite. Laboratory and bench-scale work have been carried out and a larger process development unit is undergoing shakedown runs. A number of equipment failures have prevented the completion of these runs. Some of the failed equipment is being replaced with Incoloy 800, which is resistant to stress corrosion cracking. New laboratory liquefaction results are reported. The estimated capital and operating costs of a plant for making synthesis gas are 3-1/2 times those estimated earlier, due to the inclusion of more areas and an increase in the cost of those areas considered previously. Operating costs are lower in North Dakota due to lower raw material and labor costs.

NTIS FE-1224-49

6.1.85

COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR OCTOBER 1975

Oak Ridge National Laboratory, Tenn.

Dec 75 21p

Contract: W-7405-eng-26

Monitor: 18

Abstract: This report, the fifteenth of a series, is a compendium of monthly progress reports for the ORNL research and development projects that are in support of the increased utilization of coal as a source of clean energy. The projects reported this month include those for hydrocarbonization, solid-liquid separations, chemical research and development, analytical chemistry, engineering evaluations of nuclear process heat for coal conversion, coal-fueled MIUS, engineering evaluations of the Hydrocarbonization and Synthoil processes, and biomedical and environmental research.

NTIS ORNL-TM-5186

6.1.86

COAL TECHNOLOGY PROGRAM QUARTERLY PROGRESS REPORT FOR THE PERIOD ENDING SEPTEMBER 30, 1975

Oak Ridge National Laboratory, Tenn.

Dec 75 69p

Contract: W-7405-eng-26

Monitor: 18

Abstract: In hydrocarbon research the effort in experimental development focused upon modification of the atmospheric pressure reactor and successful completion of the first two runs using H_2 as the fluidizing gas. Effort was focused on installation and initial shakedown testing of the bench-scale hydrocarbonization system that is designed to process coal at a nominal rate of 10 lb/hr at pressures up to 300 psig and temperatures up to 1200°F. In solid-liquids separation work, solvent agglomeration-fractionation (SAF), followed by settling at elevated temperatures and pressures, continues to show promise as a solids separation scheme for Solvent Refined Coal (SRC) and similar processes. A preliminary economic evaluation of SAF, followed by settling and filtration of the bottoms material, shows a significant cost advantage over conventional rotary drum filtration. In the engineering evaluations of nuclear process heat for coal conversion, a preliminary study of the energy intensiveness and unit costs of various energy transportation modes was completed. A pressurized gasifier was selected and process flowsheets and material balances for the gasifier and gas-treating section were prepared for Synthoil. Research in the biomedical and environmental program continues.

NTIS ORNL- 5093

6.1.87

HYDROGENATION OF WESTERN COAL IN DILUTE PHASE UNDER MEDIUM PRESSURES FOR PRODUCTION OF LIQUIDS AND GASES. FINAL REPORT

Utah Univ., Salt Lake City, Dept. of Mining, Metallurgical and Fuels Engineering.

Wiser, W. H.

Dec 75 151p

Energy Research and Development Administration Contract: FE(49-18-1200

Monitor: 18

Abstract: Previous research conducted at the University of Utah indicated a possibility for a short residence time conversion of coal to useful liquid and gaseous fuels. This concept was tested in short (6 ft.), small diameter tubes at high temperatures (2000 psi hydrogen pressure and 650 to 700°C) and then extended to longer tubes at lower temperatures (1800 psi hydrogen pressure at 480-520°C). An application of 5 percent $ZnCl_2$ to the coal results in 70-75 percent conversion of coal matter to liquid and gaseous fuels at a coal feed rate of 1/2 pound of coal per minute in a 1/4" tube 100 ft. long. Many problems associated with this process have been investigated. These range from residence time measurements, prospective catalyst screening and catalyst recovery to processing, upgrading and characterizing products. Further areas of inquiry have been studies of catalyst-coal interactions and development of new catalysts and procedures for using available catalysts with coal syncrudes produced by the $ZnCl_2$ method. Details of these investigations are reported here and in other technical reports that have resulted. Specific literature references are provided.

NTIS FE-1200-1

6.1.88

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL. VOLUME IV. PRODUCT STUDIES, PART 5. DEVELOPMENTAL AND RATE STUDIES IN PROCESSING OF COAL MINERALS

Washington State Univ., Pullman Research Div.

Author: Jensen, G. A.

137p

Contract: 14-01-0001-496

Monitor: 18

Abstract: Large-scale coal processing by solvent refining is expected soon. Solvent refining produces a liquefiable, ash-free product and a carbon-containing residue that has been named coal minerals. The chemical reactions and kinetics of carbon removal and iron reduction from Kentucky No. 9 coal minerals were studied.

NTIS OCR-53-INT-13

6.1.89
EVALUATION OF GASIFICATION AND LIQUEFACTION PROCESSES USING NORTH DAKOTA
LIGNITE

University of North Dakota, Grand Forks, N.D. 1975
Engineering Experiment Station
Baria, D. N.

6.1.90
PROJECT LIGNITE. QUARTERLY TECHNICAL PROGRESS REPORT NO. 7. OCTOBER,
NOVEMBER, AND DECEMBER 1975

North Dakota Univ., Grand Forks. Engineering Experiment Station.
Energy Research and Development Administration Contract: E(49-18-1224
Severson, D. E.
22 Jan 76 74p
Contract: E(49-18)-1224
Monitor: 18

Abstract: The operability of the Solid-Liquid Separation Unit using toluene as a solvent for settling-deashing of undeashed solvent refined coal (SRC) was established. Deashed product was very low in ash, but with a low melting point (100-130°F). Some operational difficulties remain but these are associated with incomplete solution and poor mixing of the undeashed SRC and the solvent. The Incoloy 800 dissolvers and the sandbath-preheater coil were installed. All of the high-pressure, high-temperature service tubing was also replaced with Incoloy. Batch-autoclave settling tests for separation of liquefied coal from the mineral matter and unreacted coal showed that toluene was a more satisfactory solvent than benzene or methyl isobutyl ketone. Separations were similar with toluene and benzene, but could be attained at a lower pressure and temperature with toluene. Carbonization of lignite has been studied both experimentally and by literature survey in an effort to incorporate pyrolysis technology in the conceptual framework of a lignite refinery. A fundamental limitation noted was that any appreciable pyrolysis (even drying) significantly decreased the reactivity during liquefaction. An evaluation made of a plant for converting lignite by liquefaction into co-products of SRL and a light oil indicated a selling price of \$1.53/MM Btu for the co-products was required for a 12 percent DCF return.

NTIS FE-1224-52

6.1.91

COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR NOVEMBER 1975

Oak Ridge National Laboratory, Tenn.

Jan 76 25 p

Contract: W-7405-eng-26

Monitor: 18

Abstract: This report, the sixteenth of a series, is a compendium of monthly progress reports for the ORNL research and development projects that are in support of the increased utilization of coal as a source of clean energy. The projects reported include those for hydrocarbonization, solid-liquid separations, chemical research and development, engineering evaluations of the Hydrocarbonization and Synthoil processes. Two shake-down runs were completed in hydrocarbonization research. Five and 20 lb. coal were pyrolyzed at ca. 1050°F under 5 atm N₂ pressure. It is hoped that H₂ will be introduced into the system in January. Batch settling tests showed that with 20% toluene settling was faster at low than at high temperatures. Additives have been found that in ppm concentrations give complete settling at very short residence times. The use of transmission electron microscopy to examine the microporosity of coals has continued. Work continues in the engineering evaluations of nuclear process heat for coal conversion. In the engineering evaluations work for Synthoil, design of the high-temperature shift section and analysis of unit reactor vessels were initiated.

NTIS ORNL-TM-5214

6.1.92

SOLVENT REFINING OF WYODAK, ILLINOIS NO. 6 (MONTEREY MINE) AND BLACK MESA COALS. VOLUME 2

Hydrocarbon Research, Inc., Trenton, N.J.

Electric Power Research Inst., Palo Alto, Calif.

Final report

Johnson, Edwin

Feb 76 327p

Project: EPRI-389, EPRI-340

Monitor: EPRI-389-FR

See also Volume 1, PB-243 875.

Abstract: An experimental program of two continuous bench unit runs (Runs 177-114 and 177-115) was funded and carried out to generate background information on the results of SRC processing of Wyodak coal containing about 0.51 wt.% org. sulfur. This report summarizes product distribution data at each operating condition, hydrogen consumption data, elemental analyses of products and product fractions for sulfur, nitrogen, carbon and hydrogen. The principal results and product properties are correlated with operating conditions. A critical evaluation of the effect of startup solvent and recycle solvent upon coal conversion is presented. This report also includes the final report for project 340.

NTIS PB-253 531/8ST

6.1.93

COAL TECHNOLOGY PROGRAM QUARTERLY PROGRESS REPORT FOR THE PERIOD ENDING
DECEMBER 31, 1975.

Oak Ridge National Laboratory, Tenn

Mar 76 81p

Contract: W-7405-eng-26

Monitor: 18

Abstract: Installation of the bench-scale hydrocarbonization research system was completed and initial pressurization was followed by heat up, leak checking, and testing of instrumentation. Shakedown runs were completed using 5 and 20 lbs of pulverized coal as feed and pyrolyzing the coal at approx. 1050°F under 5 atm of nitrogen pressure. Some excellent results have been obtained in the additive agglomeration studies using liquid additives designed for the petroleum industry. Characterization studies of SRC oils continue using a number of methods. Studies have continued on several aspects of the physical structure of coal, the sorption and desorption of water vapor on a cobalt-molybdenum catalyst, and the catalytic chemistry of the same catalyst. Synthoil and COED process oil samples have been chemically fractionated for biological and chemical characterization. Development continues on achieving cleaner fractionation of chemical classes than has previously been afforded by more conventional schemes. Studies have begun to characterize aqueous effluents from the synthane process and in-situ shale oil retorting. Engineering evaluations of several processes are reported. Investigation into the fate and availability of a model PAH compound in water has begun. Acquisition of literature on the bioaccumulation and toxicity of trace elements released in aqueous effluents from coal conversion processes has been completed. In the engineering evaluations of nuclear process heat for coal conversion, preliminary design of a plant for steam gasifying coal with VHTR heat has been completed.

NTIS ORNL-5120

6.1.94

COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR JANUARY 1976

Oak Ridge National Laboratory, Tenn.

Mar 76 25p

Contract: W-7405-eng-26

Monitor: 18

Abstract: This report, the eighteenth of a series, is a compendium of monthly progress reports for the ORNL research and development projects that are in support of the increased utilization of coal as a source of clean energy. The projects reported this month include those for hydrocarbonization research, solid-liquid separations, engineering evaluations of nuclear process heat for coal conversion, analytical chemistry, engineering evaluations of the Synthoil and Hydrocarbonization processes, coal-fueled MIUS, and experimental engineering support of an in-situ gasification process.

NTIS ORNL/TM-5301

6.1.95
PYROLYSIS OF DEUTERATED AND REDUCED COALS

Hacettepe University, Ankara
Gaines, A. F., Jurum, Y.
Fuel . 52.2 April 1976
129-137

Abstract: Samples of a coal and a lignite were boiled in pyridine, partially reduced and partially deuterated by modified Birch reductions. These samples were slowly pyrolysed in an inert atmosphere in a horizontal tube furnace to temperatures in the range 300-600°C. The yields and the nature of the products are reported. In particular an attempt is made to characterize the various tars, and the pyrolyses are described in terms of a simplified mechanism. It was found that boiling the fuels in pyridine increased the subsequent yield of tar and increased the proportion of high-boiling material within the tar. Tar formation was diffusion-controlled. The role of hydrogen atoms from the hydroaromatic structure of the fuels in the formation of tar, liquor and gas was confirmed. Experiments with partially deuterated fuels established that during pyrolysis interchange of hydrogen atoms occurred amongst the molecules of the gas. Further pyrolyses of partially deuterated coals under wider conditions should be profitable.

6.1.96
RESEARCH ACTIVITIES ON COAL LIQUEFACTION IN THE UNITED KINGDOM

National Coal Board, Harrow, Middlesex, Eng.
Harrison, James S.
Source: Am Chem Soc Div Pet Chem Paper v 21 n 1 Feb 1976; Symp on Coal as a Source of Chem. New York, NY Apr 4-9 1976 p 92-125

Abstract: A process description and flowsheet are presented of a method for obtaining liquid hydrocarbons from coal. The preliminary basic studies showed that coal extract can be hydrogenated successfully to distillable oils. Some insight has been gained into the hydrogenation process and problem areas have been more clearly defined. The current basic studies program includes a detailed investigation of the process with the object of providing design data for pilot plant and, ultimately, large scale plant and for investigating novel process modifications. An economic evaluation of the plant is given. 3 refs.

6.1.97
COAL TECHNOLOGY PROGRAM PROGRESS REPORT, FEBRUARY 1976

Oak Ridge National Laboratory, Tenn.
Energy Research and Development Administration
April 1976 29p
Contract: W-7405-eng-26

Abstract: Final testing of the 20-atm bench-scale system is underway in preparation for experiments with hydrogen. Laboratory-scale testing of a number of inexpensive pure compounds to improve the settling rate of

(Cont'd)

Aqueous by-products from coal conversion technologies and oil shale retorting have been analyzed for major organic components. A report is being prepared discussing various aspects of the engineering evaluations of nuclear process for coal. A bench-scale test program on thermo-chemical water splitting for hydrogen production is under consideration. In the coal-fueled MIUS program, preparations for procurement of tubing for the matrix in the fluidized-bed furnace and for fabrication of the recuperator under coal-fueled MIUS operating conditions are near completion. Process flow diagrams and heat and material balances were completed for most of the units in the wynthoil process. Overall utilities requirements were calculated and the coal preparation flowsheets were finalized. For hydrocarbonization, the flowsheet was revised to include additional coal data. Flowsheets were finalized for the acid gas separation and recycle, and the oil-solids separation.

NTIS ORNL/TM-5321

6.1.98

PROCESS FOR THE EXTRACTION OF COAL

Kimber, G. M.
To Coal Industry (Patents) Ltd.
Patent
German (FRG) Patent 2,548,946.A
20 May 1976

Abstract: A method is named to extract coal in which coal is heated with an extracting agent to a temperature in the region of 300-500°C. The following extracting agents are named: A) Highly aromatic petroleum fraction which boils in the region of 200-500°C and has an atomic ratio of H:C under 1.1; B) As petroleum fraction one can use sooty oil, thermal tar, cat cracking sludge or coking oil distillate or mixtures of these; C) A mixture of the petroleum fraction with anthracene oil; D) extracting agents, of which not more than 20 wt.% boil below 300°C. 3 tabs.

6.1.99

ROLE OF SOLVENT IN THE SOLVENT REFINED COAL PROCESS

Kang, C. C. (Hydrocarbon Research, Inc., Trenton), Nongbri, G.; Stewart, N.
9 Refs.
American Chemical Society, Div. Fuel Chem., Prepar. 21/5/76. 19-31
American Chemical Society Meeting - San Francisco, California.
20 August 1976

Abstract: A preliminary study of the effect of solvent upon SRC process performances was undertaken. The startup solvent and makeup solvent have a significant effect upon coal conversion. However, the use of a good startup solvent does not sustain good process performance under unfavorable
(Cont'd)

process conditions and vice versa. Hydroaromatics, represented by H_# from NMR analysis, other than tetralin, also possess hydrogen donor capabilities. These hydroaromatics could be better donors than tetralin. This conclusion was reached during a process study of the Black Mesa coal, a subbituminous coal. At the same hydrogen pressure, an increase in reactor temperature resulted in higher hydrogen consumption, lower coal conversion and higher dry gas (C₁-C₃) production. These observations were accompanied by a deterioration in solvent properties (as shown by the lower tetralin to naphthalene ratio and lower H_# value) and significant amount of coke formation. These findings support a hypothesis that coke formation results when thermal cracking gets ahead of hydrogenation which is catalyzed by the hydrogen donors present in the solvent.

6.1.100

KINETICS AND SOLUBILITY OF HYDROGEN IN COAL LIQUEFACTION REACTIONS

Guin, J. A., Tarrer, A. R., Pitts, W. S., Prather, J. W.

Auburn University, Alabama

26 Refs.

American Chemical Society, Div. Fuel Chem., Prepr. 21/5/1976, 170-188

American Chemical Society Meeting

San Francisco, California, USA

29 Aug 1976

Abstract: The macroscopic kinetics of hydrogenation reactions occurring during coal liquefaction are studied. Experimental data for the solubility of hydrogen in creosote oil are represented by Henry's Law coefficients and are used for modeling hydrogen consumption of kinetics. Mass transfer influence is observed to be negligible, and overall hydrogen consumption rate is shown to be governed by chemical kinetics alone.

6.1.101

HIGH PRESSURE LIQUID CHROMATOGRAPHIC STUDIES OF COAL LIQUEFACTION KINETICS

Prather, J. W., Tarrer, A. R., Glin, J. A., Johnson, D. R., Neely, W. C.

Auburn University, Alabama

10 Refs.

American Chemical Society, Div. Fuel Chem., Prepr. 21/5/1976 144-153

American Chemical Society Meeting

San Francisco, California, USA

29 Aug. 1976

Abstract: High pressure liquid chromatography (HPLC) provides a fast, relatively simple analytical method for analysis of the complex organic mixtures found in coal liquefaction processes. This technique offers distinct advantages over the more commonly used technique of gas chromatography. The feasibility of using HPLC to characterize products from
(Cont'd)

liquefaction processes such as the solvent refined coal (SRC) process are reported. Quantitation of chromatograms has been accomplished by assuming a Gaussian waveform and using a least squares method for computing peak areas relative to that of an internal standard. The effects of catalytic agents, namely, a commercial Co-Mo-Al catalyst, iron pyrite, mineral residue from the Wilsonville SRC pilot plant, coal ash, and process variables such as hydrogen partial pressure and temperature on the chemical composition of process solvent (creosote oil) and, also, of the liquid fraction of solvent/coal slurries during hydrogenation and hydrodesulfurization have been followed using HPLC. In doing so, the changes in composition of specific major constituents have been monitored with reaction.

6.1.102

SHORT CONTACT TIME COAL LIQUEFACTION. I. TECHNIQUES AND PRODUCT DISTRIBUTIONS

Whitehurst, D. D., Mitchell, T. O.

Mobil Research and Development Corp., Princeton, N.J.

2 Refs.

American Chemical Society, Div. Fuel Chem., Prepr. 21/5/1976 127-143

American Chemical Society Meeting

San Francisco, California, USA

29 Aug 1976

Abstract: Coal liquefaction, as exemplified by the solvent refined coal process, has been studied in a short contact time stirred reactor. The design and operation of the reactor system and work-up and analysis of the products are described in detail. Contact times as short as 0.5 min. have been obtained routinely. A synthetic recycle solvent has been developed. It matches the chemical properties of the true coal-derived recycle solvents, but can be distinguished from liquefaction products. From changes in the solvent composition, H-consumption by coal can be calculated. A series of runs with West Kentucky and Wyodak coals is described. Results presented include the product distributions as functions of time, temperature, H-donor ability of the solvent, nature of the gas, H-consumption, and oxygen removal. It is shown that little hydrogen consumption is required for dissolution and removal of approximately 40 percent of the organic oxygen and sulfur. The molecular weight distribution vs. conversion reveals that the initial product appears to contain a significant high molecular weight (greater than 2000) component that is rapidly destroyed. High SRC yields are obtained early in the reaction. Improvement of SRC quality is accompanied by a decrease in yield and a large increase in hydrogen consumption.

6.1.103

EFFECT OF COAL MINERALS ON REACTION RATES DURING COAL LIQUEFACTION

Tarrer, A. R., Guin, J. A., Pitts, W. S., Henley, J. P., Prather, J.W., and Styles, G. A.

Auburn University, Alabama

12 Refs.

American Chemical Society, Div. Fuel Chem., Prepr. 21/5/1976 59-77

American Chemical Society Meeting

San Francisco, California, USA

(Cont'd)

Abstract: The effect of coal minerals in promoting reaction rates during coal liquefaction are studied. Ten different coal minerals as well as coal ash and actual SRC residue from the Wilsonville Pilot Plant have been individually screened to rate their catalytic activity on hydrogenation and hydrodesulfurization of creosote oil relative to that of a commercial Co-Mo-Al catalyst. In addition the effect of recycling mineral matter from successive batch autoclave runs is also studied. The results show conclusively that certain coal derived minerals increase both hydrogenation and hydrodesulfurization activity during coal liquefaction, with iron compounds being second to the Co-Mo-Al in increasing reaction activity. Most interesting is that filter cake residue from the Wilsonville pilot plant proved to be one of the more active catalytic agents. Also, the physical state (particle size) and agitation as well as chemical composition of mineral matter are shown to influence significantly its effect on reaction rates. In support of the screening results, moreover, continued recycle of mineral matter residue is shown to lead to increased reaction rates.

6.1.104

COAL TECHNOLOGY PROGRAM PROGRESS REPORT, MARCH 1976

Oak Ridge National Laboratory, Tenn.
Energy Research and Development Admin. - May 76 29p

Contract: W-7405-eng-26

Monitor: 18

Abstract: Shakedown tests of bench-scale hydrocarbonization system were successfully completed. Wyodak coal was fed to the reactor at a rate of 9.9 lb/hr where it was hydrocarbonized at 1050°F under 20-atm hydrogen pressure. Laboratory results including settline tests, bench-scale settline tests and sample aging tests were continued. Two of ten compounds tested with the laboratory-scale apparatus were effective in increasing settling rates of solids in Solvent Refined Coal unfiltered oil, but bench-scale tests failed to show any improvements in the settline rate over the untreated SRC-UFO. Analytical chemistry efforts involved the removal and concentration of organic components in by-product waters from fossil fuel conversion processes. A sephadex gel is being used to achieve hydrophilic-lipophilic separations in organic mixtures as a step in the analysis of fossil fuel related materials. Engineering evaluations of the Synthoil and Hydrocarbonization processes continued with the Synthoil process flow diagrams, heat and material balances, and utilities requirements being completed. Inspection techniques were developed for wear- and process-resistant coatings. Orders were placed for the Incoloy 800 tubing and a smaller quantity of Inconel 600 tubing for the tube matrix in the coal-fueled MIUS fluidized bed. An engineering feasibility review of General Atomic's proposal to ERDA for a bench-scale test program on thermochemical water splitting for hydrogen production was completed.

NTIS ORNL/TM-5430

6.1.105

COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR MAY 1976

Oak Ridge National Laboratory, Tenn.

Energy Research and Development Admin. - June 76 25 p

Contract: W-7405-eng-26

Monitor: 18

Abstract: In the Hydrocarbonization project, two successful experiments were completed in the bench-scale hydrocarbonizer. In the Solids-Liquid Separations project, initial filtration runs on the bench-scale filter employed a 40- μ metal disc filter.² Filtration rates for PAMCO-SRC at 500°F were as high as 165 lb/hr. ft², but decreased rapidly with cake thickness. High-temperature pyrolysis studies of large coal blocks were significantly interrupted by equipment problems which developed. Several tests at 800°C were completed, however, with the continued production of pyrophoric chars at external heating rates of 0.3 and 3.0°C/min. Samples of Synthoil, shale oil, crude petroleum, and by-product waters from oil shale retorting and Synthane coal gasification have been chemically fractionated and are being examined for biological activity. Normal alkanes in oil shale and by-product retort water have been determined. Polycyclic aromatic hydrocarbon (PAH) fractions have been prepared from extracted organics removed from shale oil by-product water and Synthane condensate water. In the conceptual design study of the Synthoil process, preliminary figures indicate that the overall capital cost estimate for the commercial-scale (100,000 bbl/day) plant will be in the neighborhood of \$2 billion. Work continued on the estimation of operating costs. In the Hydrocarbonization conceptual design study, the major effort was placed upon capital and operating cost estimation. In Coal-fueled MIUS, because of excellent progress in preparation of tube bundle drawings and specifications, it was decided to hold the furnace housing bid request in order to send out a combined furnace and tube bundle bid package.

NTIS ORNL/TM-5532

6.1.106

PROJECT LIGNITE. QUARTERLY TECHNICAL PROGRESS REPORT NO. 8. January, February and March 1976

North Dakota University, Grand Forks. Engineering Experiment Station.

*Energy Research and Development Admin.

Severson, D. E.

14 July 1976 65 p

Contract: E(49-18)-1224

Monitor: 18

Abstract: Project Lignite was established in 1972 for the purpose of determining the appropriate technological approach to the conversion of Northern Great Plains lignite to premium solid, liquid and gaseous fuels. In keeping with this objective, laboratory and bench-scale work have been carried out and a continuous process development unit is being operated to demonstrate the feasibility of liquefaction of lignite. The continuous process currently

(Cont'd)

under development is the two stage conversion of lignite to fuel liquids with solvent-refined lignite as an intermediate product. The first state is a unit converting 50 pounds per hour of raw lignite into solvent-refined lignite by reaction with synthesis gas (carbon monoxide and hydrogen) in the presence of a hydrogen donor solvent that is continually regenerated from the lignite during processing. The mineral separations system is a countercurrent decantation process carried out at elevated temperature and pressure. The second stage will be the catalytic hydrogenation to premium liquid fuels of the solvent-refined lignite produced in the first state.

NTIS FE-1224-58

6.1.107

CHEMISTRY OF LIGNITE LIQUEFACTION. QUARTERLY REPORT, APRIL-JUNE 1976

Stenberg, V. I., Baltisberger, R. J., Klabunde, K. J., Woolsey, N. F., Severson, E., Souby, M.
North Dakota University, Grand Forks, USA
Contract: E(49-18)-2211
July 1976

Abstract: Studies on the separation of the major groups of SRL are continuing. The solvent for the elution from the ion exchange resin was selected to be tetrahydrofuran because of its ease of removal from the SRL fractions and ability to dissolve high percentage of SRL by use of a strongly acidic ion exchange column. The SRL was separated into the basic fraction and a neutral-acidic fraction. The latter accounts for 68 percent of the SRL. It has the average molecular weight of 295. This starting SRL sample has the average molecular weight of 400. The vapor phase osmometer for molecular weight determination has been installed and checked for accuracy. A matrix solution computer program for data analysis was developed for a basis set of up to 30 compounds and up to 30 data points. The program converges when the basis set is reduced to 2-, 3-, 4-, 5- and 6- ring compounds. The solvent for the UV data collection was selected to be N, N-Dimethylacetamide because of its dissolving power for the materials to be analyzed and its maximum UV transmission. The UV spectra of 20 model compounds were obtained in preparation of the testing of the computer program for nonsynthetic laboratory data. A second computer program (vector compound solution) is being developed. This differs from the matrix solution in that the program potentially selects its own basis set whereas the basis set must be selected for the matrix solution. Statistical planning for Task II has been done. Two temperatures, two pressures, and two residence times are to be used. GC-MS data is presented for hydrogenation experiment illustrating that NI-W is inferior to NIMO and COMO catalysts in cracking and hydrogenation. Sixteen new catalysts designed for SRL reduction have been synthesized.

NTIS FE-2211-1

6.1.108

COAL TECHNOLOGY PROGRAM. QUARTERLY PROGRESS REPORT FOR THE PERIOD ENDING MARCH 31, 1976

Oak Ridge National Lab., Tenn.

Energy Research and Development Admin. - July 76 134p

Contract: W-7405-eng-26

Monitor: 18

Abstract: ORNL's progress in coal research programs is reported: coal gasification and coal liquefaction (hydrocarbonization, residue carbonization, solids removal from coal liquids, pyrolysis, in-site gasification, synthoil process, analytical chemistry (of by-products, effluents, etc.), environmental effects (including study of carcinogens, mutagens, etc.), trace elements materials technology, nondestructive testing, chemical research, and possible applications of process heat reactors.

NTIS ORNL-5159

6.1.109

PRODUCTION OF LOW SULFUR FUEL OILS FROM UTAH COALS

Qader, S. A., Hill, G. R.

University of Utah, Salt Lake City

Advanced Chemical Series n 127, 1973, for Meeting

American Chemical Society, New York, NY Aug 29-30, 1972. P 91-97

Abstract: Low sulfur fuel oils were prepared from a high volatile bituminous coal by hydrogenation under high temperatures and pressures. At a coal conversion of 80%, the ratio of oil-to-gas yields was about three, and 23% of the coal sulfur was contained in the oil. Sulfur content of the oil, however, remained the same at different coal conversion levels. The data obtained in the semi-continuous, dilute phase hydrogenation system showed that the whole oil can be directly used as a fuel oil where 1% sulfur is tolerated. Fuel oils containing 0.5 and 0.25% sulfur were produced by desulfurization of the whole oil. A preliminary economic evaluation indicated that low sulfur fuel oils can be produced from coal by hydrogenation at a manufacturing cost of about \$5-6 per barrel. 6 refs.

6.1.110

LIQUEFACTION OF COAL WITHOUT CATALYST USING SELECTIVE HYDROGENATION

Gleim, W. K. T.

University of Southern California, Los Angeles

American Chemical Society Div Fuel Chem. Prepr v 21 n 5 1976:

Symposium on Coal Liquefaction, 172nd National Meeting, San Francisco, Ca. Aug 29-Sep 3 1976 p 91-95

Abstract: This paper discusses the technological and economic aspects of coal liquefaction system in which coal hydrogenation takes place without catalyst in thermohydrocracking process. In this system the heptane soluble fraction of coal, obtained by selective extraction with hydrocracked vacuum bottoms from petroleum refineries, are converted at high pressure of hydrogen. 7 refs.

6.1.111

COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR JULY 1976

Oak Ridge National Laboratory, Tenn.

Energy Research and Development Admin. - Sep 76 33 p

Contract: W-7405-eng-26

Monitor: 18

Abstract: The bench-scale hydrocarbonization system was modified to permit recirculating fluidized-bed operation. Three residue carbonization runs were performed. In solids-liquid separations work, a sealed filtrate weighing unit was installed in the bench-scale apparatus that will allow continuous print-outs of filtration rates at operating pressures downstream of the filter up to 150 lb/in. Settling runs at 530°F with process solvents and oil from the P and M-SRC pilot plant have shown excellent results; twenty percent light process oil gave settling rates which were more than double those obtained with SRC-unfiltered oil alone. High-temperature (greater than 873° K) pyrolysis tests with large blocks of coal produce significantly greater quantities of gas than that produced by pyrolysis of powdered coal. Work was completed on capital and operating cost estimates and economic analyses in conceptual design studies of commercial-scale Synthoil and Hydrocarbonization plants. In the Coal-Fueled MIUS program work continued on analysis of the turbine electronic control system, design of building modifications, endurance testing of coal feed systems and a prototype feed nozzle, and supplemental studies. In materials engineering work, the assessment for the pressure vessel and piping technology project, inspection techniques for wear and process-resistant coatings, and conceptual design studies of prestressed concrete pressure vessels for gasifier applications were continued.

NTIS ORNL/TM-5611

6.1.112

CHEMISTRY OF LIGNITE LIQUEFACTION. QUARTERLY REPORT, JULY-SEPTEMBER 1976

Stenberg, V. I.

North Dakota University, Grand Forks (USA)

Contract Ex-76-C-01-2211

Oct 1976

Abstract: Studies in the separation of the major groups of SRL are now discontinued due to reaction of the ion exchange resin with the solvent, non-quantitative recovery of the sample from the ion exchange resin, and efforts underway at the Pittsburgh Energy Research Center to find an optimum procedure for this purpose. One of the two computerized methods of analysis for handling various types of input data has been developed to the point that laboratory UV data are being put into it. Additional more accurate laboratory data have been obtained on the basis set of 20 compounds. The initial inaccuracy occurred because of under-specification performance of the Cary 14 spectrophotometer. The machine was repaired and the data retaken. The one-liter batch autoclave studies are continuing using catalysts for the
(Cont'd)

upgrading of SRL. These were tested and the results reported herein are very interesting. They show comparable activity to the best of the commercial catalysts tested thus far, and have less surface area. They hold much promise for future development. The characteristics of the one-liter batch autoclave are given for temperature vs. time (to show the degree of temperature control), pressure vs. temperature (to illustrate gas consumption with temperature), and pressure vs. time (gas consumption with time). For the model compound reduction, the results for benzophenone and diphenylmethane are completed and given for benzophenone. A combination of CO and H₂ is most effective and the CO reaction is promoted by base. Diphenylmethane is difficult to reduce under these conditions. For electron spin resonance work, the Bruker Spectrometer is installed and operating, and a new vacuum line was constructed. The earlier results of the interaction of CO with NGO is being duplicated with some parts of the resultant signal not in agreement with earlier reported results.

6.1.113

PROJECT LIGNITE. QUARTERLY TECHNICAL PROGRESS REPORT NO. 9, APRIL, MAY AND JUNE 1976 AND ANNUAL SUMMARY, FISCAL YEAR 1976

Severson, D. E.

North Dakota University, Grand Forks (USA) Engineering Experiment Station

Contract E(49-18)-1224

29 Oct 1976

Abstract: Six runs on the liquefaction section of the PDU were made, including four in which solid-liquid separation was attempted. Solvent recovery of close to 100 percent was achieved in runs at 2500 psig. Operation with one dissolver was most successful. Half a dissolver gave unacceptably low conversions. Best operating conditions to date are 750°F preheater outlet temperature, 830°F dissolver outlet temperature, 1.8 weight ratio solvent to lignite, space velocities of 1.4 for liquids and 300 for gases, and vacuum flash temperature 600°F. Conversion increases with increasing dissolver temperature but liquids yield decreases. Viscosity and melt point of vacuum bottoms increases progressively during a run. No problems have appeared in the use of Incoloy 800 dissolvers and preheaters. Piping was altered to permit solid-liquid separation ahead of vacuum flash since vacuum flash bottoms tended to be excessively viscous in the previous operation mode. An autoclave run on a lignite sample of that charged to PDU gave yields close to PDU results. A Chilean lignite was converted in the autoclave and was found to give liquid yields comparable to North Dakota lignites. Lower gas yield and water consumption, and heavier liquid products. Vapor pressure curves obtained for FS-120 solvent were slightly different from those for petroleum materials in the API Technical Data book -- Petroleum Refining.

NTIS FE-1224-61

6.1.114

COAL TECHNOLOGY PROGRAM PROGRESS REPORT, AUGUST 1976

Oak Ridge National Laboratory, Tenn.

Energy Research and Development Admin. - Oct 76 29p

Contract: W-7405-eng-26

Monitor: 18

Abstract: The first experiment utilizing the hydrocarbonization reactor in a recirculating fluidized bed mode was completed successfully. A residue carbonization experiment was completed in which there was no significant agglomeration in the fluidized bed reactor, but which was terminated prematurely because of a plug in the off-gas line. The characterization and settling tests of oils derived from the SRC process were continued. High-temperature coal block pyrolysis studies were completed to fill out a matrix pyrolysis data as a function of heating rates at atmospheric pressure. Engineering evaluations of commercial-sized Synthoil and Hydrocarbonization plants were completed. In the Coal-Fueled MIUS project bids were received for fabrication of the fluidized bed combustor and tests of system components continued. Experiments were made to develop inspection techniques for thin coatings and design studies of prestressed concrete pressure vessels continued. The assembly of apparatus for measuring the formation rates of metal carbonyls was completed. A new project to provide process and program analysis studies for the ERDA Fossil Energy Office of Program Planning and Analysis was initiated. A new project to develop better contactors for the noncatalytic hydroliquefaction of coal was stated.

NTIS ORNL/TM/5654

6.1.115

COAL TECHNOLOGY PROGRAM, ANNUAL INTERIM REPORT FOR FISCAL YEAR ENDING JUNE 30, 1976

Oak Ridge National Laboratory, Tenn.

Energy Research and Development Admin. - Oct 76 203p

Contract: W-7405-eng-26

Monitor: 18

Abstract: ORNL's progress in coal research programs is reported: coal gasification and coal liquefaction (hydrocarbonization), residue carbonization, solids removal from coal liquids, pyrolysis, in-situ gasification, Synthoil process, and analytical chemistry (of by-products, effluents, etc.) environmental effects (including study of carcinogens, mutagens, etc.), trace elements, materials technology, nondestructive testing, clinical research, and possible applications of process heat reactors.

NTIS ORNL-5208

6.1.116

CHANGES IN THE PORE STRUCTURE OF COAL WITH CHEMICAL PROCESSING

Booras, G. S., Peter Sen, E. E.
California University, Berkeley (USA) Lawrence Berkeley Lab.

31 Refs

Contract W-7405-eng-48

1976

Dept. NTIS

1 112 800

Abstract: Carbon dioxide adsorption experiments gave the same BET surface areas at room temperature and at dry ice temperature for a molecular sieve, an alumina catalyst, and a Wyoming subbituminous coal. This suggested that activated diffusion was not an important factor, even at 196°K. However, the adsorption of CO₂ on Illinois No. 6 coal decreased with increasing temperature. Surface area variations of desulfurized coal, extracted coal, and reacted coal were examined by carbon dioxide adsorption at 196°K. The use of NaOH to remove S from Illinois No. 6 coal appeared to cause partial blockage or collapsing of the pore structure. Subsequent extraction removed these obstructions somewhat. This conclusion was suggested by a minimum in the curve of surface area vs. extraction time. Pyridine extractions of Roland seam coal appeared to open new areas that were previously inaccessible to carbon dioxide. The surface areas were nearly doubled, but the average pore diameter appeared to remain essentially unchanged as evidenced by neopentane adsorptions. Large solvent molecules such as benzene were able to penetrate the coal pores, whereas a large, symmetrical molecule such as neopentane could not. These results suggest that the pores are slot shaped rather than cylindrical.

6.1.117

COAL TECHNOLOGY PROGRAM. QUARTERLY PROGRESS REPORT FOR THE PERIOD ENDING SEPTEMBER 30, 1976

Oak Ridge National Laboratory, Tenn

Contract W-7405-eng-26

Jan 1977

Abstract: This quarterly report covers the progress made during the period July 1 through September 30 for the Oak Ridge National Laboratory Research and Development projects that are carried out in support of the increased utilization of coal as a source of clean energy. These projects are supported by the ERDA Divisions of Coal Conversion and Utilization, Fossil Demonstration Plants, Fossil Energy Research, Physical Research, and Biomedical and Environmental Research and by the EPA Office of Research and Development through interagency agreement with the ERDA. The report is divided into the following sections: Hydrocarbonization Research and Residue Carbonization Projects, Supporting Research and Development in Separations Technology, Experimental Engineering Support of an In-Situ Gasification Process, Coal-Solvent-Hydrogen Mixing, Material Technology, Chemical Research and Development, Alkali Metal Vapor Topping Cycles, Critical Components Test Facility, Engineering Studies and Technical Support, Process and Program Analysis, and Life Sciences Program Synthetic Fuels.

6.1.118

AMERICAN CHEMICAL SOCIETY, DIVISION OF FUEL CHEMISTRY, PREPRINTS, VOLUME 21, NUMBER 5: SYMPOSIUM ON COAL LIQUEFACTION. 1976.

Anon

Am Chem Soc., Div of Fuel Chem, Washington DC

Am Chem Soc Div Fuel Chem Prepr v 21 n 5 1976, 172nd Natl Meeting, San Francisco, Calif, Aug 29-Sep 3 1976 215 p

Abstract: This volume contains proceedings of 19 papers delivered at the meeting. Among others the following subjects are covered: new materials for coal liquefaction; the role of solvent in the solvent refined coal process; deactivating of Co-Mo catalyst during coal hydrogenations; effect of coal minerals on reaction rate during coal liquefaction; liquefaction of coal without catalyst using selective hydrogenation; kinetics of coal hydrodesulfurization in a batch reactor; short contact time coal liquefaction; high pressure liquid chromatographic studies of coal liquefaction kinetics; petrographic classification of solid residue derived from the hydrogenation of bituminous coals; hydrogenation of phenanthrene over a commercial cobalt-molybdenum sulfide catalyst under severe reaction conditions; analysis of liquids from coal conversion processes. Bibliography data at end of individual articles. Each paper is abstracted and indexed separately.

6.1.119

FAST-DUMP REACTOR: AN APPARATUS TO STUDY COAL DISSOLUTION AT SHORT REACTION TIMES

Alkidas, A. C., Plett, E. G., Summerfield, M.

Aerospace and Mechanical Sciences Department, Princeton University, Princeton, NJ. Rev. Scientific Instruments, 4E, February 1977 p 154-158

Abstract: A new design for a reactor is described for studying the dissolution of coal in organic solvents at short reaction times. This reactor utilizes a gas pressure forced injection system to permit rapid injection and movable reaction chamber floor to allow the discharge of the reactants for rapid quenching. Dissolution studies have been performed at reaction temperatures of up to 470°C and pressures of up to 115 atm. Quenching times of the reactants of the order of 1 sec. are achieved routinely. Typical results are presented to show the versatility of the apparatus.

6.1.120

SYMPOSIUM ON DESULFURIZATION OF COAL AND COAL CHAR; SYMPOSIUM ON CHEMICALS FROM COAL; GENERAL PAPERS, 1977

Anon

Am Chem Soc, Div of Fuel Chem, Washington, DC

Am Chem Soc Div Fuel Chem Prepr v 22 n 2 1977, at 173rd Natl Meet, New Orleans, La. Mar 21-25 1977 252 p

Abstract: This volume contains proceedings of 27 papers delivered at the meeting. Thirteen papers covered various aspects of the desulfurization of coal and char-coal. Five papers reported on research works aimed at the synthesis of chemicals
(Cont'd)

from coal derivatives (synthesis gas, tar); eight general papers discussed - among others - the following subjects: gasification of Iowa coal in the synthane PDV gasifier; hydrodesulfurization in the Solvent Refined Coal Process; preparative CGPC separations of solvent refined coals; aging characteristics of coal liquids; pyrolysis of Western coal and liquefaction for char and oil production. Most papers are accompanied by bibliography data. Each contribution is abstracted and indexed separately.

6.1.121

HYDRODESULFURIZATION IN THE SOLVENT REFINED COAL PROCESS.

Pitts, W. S.; Tarrer, A. R.; Guin, J. A.; Prather, J. W.
Auburn Univ., Ala

Am Chem Soc Div Fuel Chem Prepr v 22 n 2 1977, at 173rd Natl Meet: Gen Pap,
New Orleans, La., Mar 21-25 1977 p 214-224

Abstract: The Solvent Refined Coal (SRC) process is currently recognized as one of the more promising processes for producing an environmentally acceptable boiler fuel from coal. In the SRC process, coal is liquefied to allow removal of entrained mineral matter by physical separation methods and reacted with hydrogen to remove chemically part of its organic sulfur. A discussion of catalytic reactions taking place in the SRC process is followed by consideration of hydrodesulfurization kinetics. It is shown that hydrodesulfurization reactions occur, under reaction conditions used in the SRC process, at a rate that is practically independent of hydrogen concentration. Reduced iron has catalytic effect on HDS reactions. The retardation of HDS reactions by H_2S product is due to catalytic inhibition as well as thermodynamic effects. HDS reactions can be modeled as two first-order reactions occurring in parallel, with two widely different rate constants. Extensive experimental data are included in this report. 8 refs.

6.1.122

COAL LIQUEFACTION BY AROMATIC INTERCHANGE WITH PHENOL AND CATALYTIC HYDROGENOLYSIS

Moore, R. H.; Martin, C. E.; Cox, J. L.; Elliott, D. C.
Battelle Pac Northwest Lab, Richland, Wash

Am Chem Soc Div Pet Chem Prepr v 22 n 2 Mar 1977; Recent Adv in Alkylation,
New Orleans, La., Mar 20-25 1977 p 446-461

Abstract: This study was conducted to assess the behavior of various coals with respect to solubilization by acid catalyzed depolymerization with phenol. Ash removal, phenol uptake, and reactions of other solvent systems were considered and the hydrogenolysis of a number of coals and of their depolymerized products were compared. 17 refs.

6.2 COAL LIQUEFACTION PROCESS REVIEWS (GENERAL INTEREST)

This is a category of publications which are oriented towards providing general information on liquefaction of bituminous coals and lignite. Most of these articles are descriptive, historical or philosophical essays. There are papers that give a quick review of several coal liquefaction processes. Others describe the potential of SRC as a utility fuel or for SO₂ emission control. Some narrate the research and development efforts that have been made or are ongoing in the field of coal liquefaction technology in the Western hemisphere or overseas.

A few papers are written from the point of view of private industry, its attitudes and strategies on clean energy from coal and the factors that play a role in decision making processes. Prospects and projections on the future of the process are also covered.

There are articles on the description of SRC pilot plant and demonstration plants as well as U.S. government studies on synthetic fuel commercialization.

Authors of these papers have come from universities, government agencies, manufacturing industries and engineering companies.

6.2.1

THE POSSIBILITIES OF SOLVENT REFINED COAL

George Washington University, Washington, D.C.
School of Engineering and Applied Science.

AUTHOR: Jameson, Robert M.
22 February 65 142p

ABSTRACT: The broader utilization of coal is often hampered by coal's physical properties and its high ash and sulfur content. Coal's physical properties can be favorably altered and its ash and sulfur content greatly reduced by solvent refining. The thesis describes a process for solvent refining of coal and applies a production cost formula to estimate the selling price of refined coal in various sections of the world. Utilizing these prices as a base the potential size of the competitive market available to solvent refined coal is estimated up to the year 1980. Sizeable economically competitive markets became apparent in the combustion, metallurgical, and diesel propulsion fields. These markets are estimated at a total of 103 million tons by 1970 and 217 million tons by 1980. Certain technological unknowns obscured the assurance of the various important markets; thus, other than show the prominent market possibilities, the study reveals a clear order of additional research needed to determine the reality of the estimates. (Author)

CFSTI - PB-167 628

6.2.2

HYDROGENATION OF COAL AND TAR

Bureau of Mines, Washington, D.C.
AUTHOR: Wu, W. B. K., Storch, H. H.
1968 204p
REPT NO: BuMines-B-633
MONITOR: 18

ABSTRACT: This bulletin traces the development of high-pressure coal and tar hydrogenation technology, based on an intensive review of the pertinent literature. The bulletin was written as part of the Bureau of Mines research program on synthetic liquid fuels. It covers the history and economics of the process; the chemical aspect of hydrogenation of coal, tar, and middle oil; the engineering aspect of converting coal and tar to liquid fuels, principally gasoline; and the equipment for the process. The literature covered includes documents of the United States and British Governments, journals, and other publications. Bureau results in the hydrogenation field are also incorporated.

NTIS - PB 233 396/1

6.2.3

LIQUID FUELS AND CHEMICALS FROM COAL

Gary, J. H.

Colorado School Mines - Mineral Industries, Bu. v12 n5 Sept 1969 15p

Abstract: Rapidly increasing liquid fuel demands and the inability of the petroleum industry to provide domestic petroleum reserves to match the increase in fuel consumption dictates the necessity for synthetic liquid fuels if the Nation's requirements are to be met. Improvements in the liquefaction processes and hydrogen production have materially lowered the costs of producing synthetic crude oils and gasoline from coal. Existing coal liquefaction processes are examined. 24 refs.

6.2.4

PROCESSES FOR COAL LIQUEFACTION AND THE PRODUCTION OF LOW SULFUR BOILER FUELS. PAPER NO. 6

Schmid, B. K., Bull, W. C.

Pittsburg and Midway Coal Co., Merriam, Kansas

Description and comparison of several processes with emphasis on solvent refined coal process.

American Chemical Society, Division of Fuel Chemistry, 162, ACS National Meeting, Washington, D. C. Sep 13-16, 1971

6.2.5

SOLVENT REFINED COAL - A POTENTIAL LOW SULFUR UTILITY FUEL

Browne, T. E.

New York State Dept. of Public Service, Office of Economic Research
Removes fly ash and sulfur

26 Oct 1971

6.2.6

SOLVENT REFINED COAL PROCESS FOR CLEAN UTILITY FUEL

Shaver, R. G.

Gen. Technol Corp., Springfield, Va.

Adv. Chem. Ser., n127, 1973, Am. Chem. Soc., New York, NY

Aug 29-30, 1972 p80-90

Abstract: Solvent-refined coal (SRC) as a de-ashed, low sulfur fuel for electric utilities is discussed from the standpoint of economics. The overall lowest delivered cost of SRC results from processing at mine-head sites because of minimized transportation costs of the ash and sulfur fractions that are eventually removed by the processing. A potential market of 300-800 million tons per year of SRC by 1990 is projected on the basis of the competitive price of delivered Btu's from low-sulfur fossil fuels and synthetic fuels at the various power-generating sites in the United States. SRC can be supplied in either a liquid or solid form: therefore it is a potentially versatile competitor for the low sulfur, fossil-fuel power generation market. 6 refs.

6.2.7

PROCESSES FOR CONVERTING COAL INTO GASEOUS AND LIQUID FUELS, PAPER
NO. SPE. 4158

Gilmore, D. W.

Bureau of Mines, Morgantown Energy Research Center, 1972

Society of Petroleum Engineers, Dallas, Texas

Eastern Regional Meeting on Processes for Converting Coal into
Gaseous and Liquid Fuels

8 Nov 1972

6.2.8

CLEAN FUELS FROM COAL

Office of Science and Technology, Washington, D. C. Overview Panel

AUTHOR: Cochran, Neal P.

10 Nov 72 15p

MONITOR: 18

ABSTRACT: Detailed study of the production of clean synthetic fuels from coal results in recommendation for a total program of \$1.51 billion. The work recommended is divided into a research phase at \$33.4 million, a development phase at \$315.0 million, and a demonstration phase at \$1.15 billion. Work is outlined for alternate processes to produce clean low-Btu gas, clean liquid fuels, and clean solid fuels from coal. Supporting work on the development of special equipment and improved materials along with economic and engineering studies are proposed and funds provided in the budget estimates.

NTIS PB-224 530/6

6.2.9

CONTROL ALTERNATIVES AND IMPLEMENTATION PATTERNS FOR THE ELECTRIC
UTILITY INDUSTRY

Hittman Associates, Inc., Columbia, Md.

Contract OST--40

Mar 1973

Hit--550

NTIS PB-224119-8

6.2.10

SOLVENT REFINING GETS THE SULFUR OUT - OF COAL

Anon

World Mining 9/6 Jul 1973

28-9

6.2.11

SUMMARY PRESENTATION: AN OVERVIEW OF COAL CONVERSION TECHNOLOGY

Waterman, W. W.

Inst. of Gas Tech., Chicago, 1973

Symposium on Clean Fuels from Coal

10 Sep 1973

6.2.12

CONTROLLING EMISSIONS FROM FOSSIL-FUELED POWER PLANTS

Powell, E. M., Ulmer, R. C.

Gasification, Solvent Extraction, and Flue Gas Desulfurization Processes
are Described

Energy, 73, Sep 1973

6.2.13

CLEAN FUELS FROM COAL. INTRODUCTION TO MODERN PROCESSES

Bodle, William W.; Vyas, K. C. (Inst. Gas Technol., Chicago, Ill.).

Clean Fuels Coal, Symp. Pap. 1973 (Pub. 1973), 49-89 (Eng.) Inst. Gas
Technol.: Chicago, Ill.

ABSTRACT: A review is given with 39 refs. of the Lurgi, Winkler, Bi-Gas, Synthane, ATGAS, HYGAS, Hydrane, Koppers-Totzek, CO₂ acceptor, Molten Salt, and U-Gas coal-to-gas processes, and the Sasol, COED, TOS Coal, Synthoil, H-Coal, CSF, and SRC coal-to-oil or coal-to-solid processes.

6.2.14

COAL IN POWER GENERATION

Reichl, E. H.

Consol Coal Co., Library, Pa.

Energy Dig v2 n6 Nov-Dec 1973 p2-6

Abstract: Techniques available for coal gasification and liquefaction are evaluated. The Lurgi process which utilizes a fixed bed, high pressure gasifier, can utilize low cost coal as feedstock. Liquefaction and methane-from-coal production costs are listed in chart form.

6.2.15

CLEAN FUELS FROM COAL, INTRODUCTION TO MODERN PROCESSES

Bodie, W. W., Vyas, K. C.
Inst. Gas Tech. Chicago, Ill.
Review with 39 References
Inst. Gas Tech., Chicago, Ill,
Chemical Fuels Coal, Symp. Pap., 1973

6.2.16

CLEAN ENERGY FROM COAL - A NATIONAL PRIORITY

US Dept. Interior, Office of Coal Research
Status of Coal Gasification, Liquefaction, and Solvent Extraction Programs
1973

6.2.17

METHODS FOR THE REMOVAL OF SULFUR FROM COAL

Dibbs, H. P., Marier, P.
Air Pollution control directorate, Ottawa, 1973

Abstract: Methods for the removal of sulfur from coal prior to combustion are reviewed, pyritic S from coal may be completely removed either by the dissolution of the coal in an organic solvent, followed by filtration to remove inorganic materials and the subsequent re-constitution of the hydrocarbon phase, or by methods based upon the selective chemical leaching of pyrite from the coal matrix. These methods are in the development stage and only the solvent refined coal process is being scaled-up to the pilot-plant level. Only coals containing 1 to 1.5 percent can be economically desulfurized by physical techniques to levels necessary to meet emission standards of the type proposed in the United States. The main benefit of the cleaning methods for high S Coals is as a primary upgrading step which allows the partially desulfurized coals to be used in conjunction with relatively low efficiency treatment methods for the removal of sulfur dioxide from flue gases.

6.2.18

COAL DISSOLUTION AND LIQUEFACTION

Briggs, D. E. Hammer, D. E.

Feb 1974

EPRI 206-C (Parts 2 and 3)

6.2.19

HOW DOES COAL FIT INTO THE ENERGY PICTURE?

Briggs, D. E.

University of Michigan, Ann Arbor

Energy, Ecol and Soc Symp Proc, Michigan State University

East Lansing, Mar 22, 1974 pl-14, publ. by Michigan Academy of Science, Arts and Letters, Eng. and Technol. Sect. Ann Arbor, 1974

Abstract: Based on a medium demand projection, the cumulative United States' energy consumption from 1974 to 2000 will be 3.7×10^{18} Btu. While nuclear power in the mid-1980s will contribute to an ever increasing share, the major fraction of the total energy will come from coal. In spite of high sulfur contents, process developments in stack gas cleaning, coal gasification, coal liquefaction and coal pyrolysis indicate that coal can be used in environmentally acceptable ways to produce (1) clean fuels for electric power generation, (2) synthetic natural gas, (3) synthetic crude oil and (4) feed stocks for chemical production. The major conversion processes are reviewed and an indication given as to how they could fit into the energy market. Cost is a prime consideration in the selection of the form of energy used. The least expensive fuel that satisfies basic needs will always be used. Synthetic crude oil and synthetic natural gas produced from coal will help stabilize world market prices of crude oil and natural gas. Diagrams illustrate economic and technical aspects. 14 refs.

6.2.20

SYSTEMS ANALYSIS FOR SO_x CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT

Foley, G. J., Smith, J. O., Schofield, W. R.

EPA, Research Triangle Park, NC

Environ. Eng. and Science Conference, 4th Annual, Proc., Louisville, Ky.

Mar 4-5, 1974 p 229, 231-255. Sponsored by Univ. of Louisville, Speed Science School, Ky, 1974

Abstract: The paper discusses development of stationary source control technology and systems analysis of sulfur and oxygen control. The system will include an emissions inventory for major sources of SO_x and cost and performance models for SO_x control technologies. These technologies include flue gas cleaning, coal cleaning, coal conversion to gas or liquids and process or combustion modifications. The system will be capable of determining the most applicable control technology for a particular source and selecting an optimum design which meets SO_x standards while minimizing cost and other impacts. The system can also evaluate the impact of potential future occurrences, such as changes in standards, energy shortages, and construction limitations.

6.2.21
COAL LIQUEFACTION

Masaic 5/2/Spr 1974
30-31

Abstract: Low-sulfur, low-ash liquid fuels for power plants have advantages over gases in that they can be manufactured and stockpiled and then distributed according to demand. Solvent-refined coal made by the SRC process can be used either as a liquid or solid. In the SRC process coal is mixed with a liquid Solvent, itself derived from the coal, then heated and passed (with additional hydrogen) to a high pressure reactor. Hydrogen and hydrogen sulfide are then separated from the mixture, it is filtered, the solvent is distilled for reuse, and the final product is recovered either as liquid or solid. Some of the sulfur-containing compounds are removed as hydrogen sulfide. The remaining inorganic sulfur and other extraneous minerals are taken out during filtration. The result is a low-sulfur (0.5) percent, low-ash (0.1 percent) fuel for power plants. Research programs are discussed briefly: mathematical models of the process, fundamental chemistry, study of cost-controlling steps, foam flotation or filtration separation of ash and effects of coal types.

6.2.22
NEW PROCESSES BRIGHTEN PROSPECTS OF SYNTHETIC FUELS FROM COAL

1974 Status
Eng. Min. Journal 175 4 Apr 1974
91-100

Abstract: An indication of the current status of each is given. The processes include Lurgi and Koppers-Totzek gasification. High-Btu gas processes--Synthane, Hygas, Bigas, CO₂-acceptor, Atgas, Kellogg, Battelle, Union Carbide and Exxon liquefaction processes--Synthoil, COED Cogas, Exxon and US Steel clean coke, Solvent Refined Coal, fluidized combustion and underground gasification are also mentioned.

6.2.23
CLEANING COAL BY SOLVENT REFINING

Josephson, J.
Environmental Science and Technology, Washington, D.C.
Environmental Science and Technology, 8/6 Jun 1974
510-11

6.2.24

CLEANING COAL BY SOLVENT REFINING

J. Josephson; Environmental Science & Technology, 1155-16th St., NW
Washington, D.C. 20036

Environmental Science & Technology, 8(6): 510-511, June 1974

Abstract: Use of solvent refined coal (SRC) to reduce air pollution is discussed. Different groups have built, or are completing SRC pilot plants, including the Pittsburgh and Midway Coal Company pilot plant near Tacoma, Washington, and a Southern Services Edison Electric Institute pilot plant at Wilsonville, Alabama. Advantages of the SRC process are higher heat values, S and ash reduction sufficient to meet EPA standards, reduced need for expensive precipitators and scrubbers, and possible economic waste reclamation. Matters under study and prospectives for SRC are described.

6.2.25

FOSSIL FUEL AND ADVANCED SYSTEMS DIVISION TECHNICAL PROGRESS REPORT

Balzhiser, R. E.

Electric Power Research Inst., Palo Alto, California

Jul 1974

NTIS EPRI-FF-1

6.2.26

SUMMARY REPORT OF VARIOUS CURRENT GOVERNMENT AND PRIVATE ACTIVITIES
IN COAL PROCESSING

Syn. Fuels 11/3/ Sep 1974

4.1-4.32

6.2.27

STATUS OF COAL LIQUEFACTION TECHNOLOGY

Epperly, W.R., Siegel, H. M.

Esso Res and Eng Co.

Intersoc Energy Convers. Eng. Conf. 9th, Proc., San Francisco, Calif.

Aug 26-30 1974 Pap 749131. p1020-1026

Available from ASME, New York, N. Y. 1974

Abstract: Three levels of processing severity are used to derive liquid fuels from coal. The least severe approach is pyrolysis in which heat is used to drive off volatile portions of the coal without adding hydrogen. Pyrolysis is nearing commercial readiness although some additional development work might be desirable. The second level involves both heat and hydrogen pressure. In this approach volatile matter is driven off and portions of the coal molecule are converted in the presence of hydrogen to lower molecular weight hydrocarbons. Processes under development require large pilot plant demonstrations. The third level of severity is gasification of coal to hydrogen and carbon oxides which are catalytically converted to liquid fuels. This approach has been demonstrated technically, but the economics are not generally favorable. 15 refs.

6.2.28

CLEAN FUELS FROM COAL

Bodie, William W.; Vyas, Kirit C. (Manage. Sci. Div., Inst. Gas Technol., Chicago, Ill.). Oil Gas J. 1974, 72(34), 73-88 (Eng.)

Abstract: A review with 68 refs. is given that includes 14 coal gasification on hydrogasification processes (Bi-gas, Hydrane, Hygas, Atgas, CO₂ acceptor, Koppers Totzek, Lurgi, molten salt, Synthane, U-Gas, Union Carbide, Wellman Galusha, Westinghouse and Winkler) and 9 coal liquefaction processes (Fischer-Tropsch, methanol synthesis, COED, Garrett, Toscoal, CSF, H-coal, SRC, and Synthoil).

6.2.29

COAL CONVERSION PROCESSES LOOM BIG AS A SOURCE OF HYDROCARBON FUELS

Boyd, N. F.

Dravo Corp, Pittsburgh, Pa.

Min. Eng. (NY) v26 n9 Sep 1974 p34-41

Abstract: Coal can be liquefied and gasified by several methods, all of which are being investigated and evaluated because each has its own advantages and disadvantages in terms of capital costs, end-products, and extent of required gas clean-up. Since coal conversion requires coal preheating to some extent, all these schemes begin with a coal-preparation step in a pressurized and heated reactor vessel where, in most cases, some additive or catalyst is usually injected. Paper reviews, based on shown flowsheets, the most important coal, gasification and liquefaction processes and outlines their present state of development.

6.2.30

CLEAN SYNTHETIC FLUID FUELS FROM COAL: SOME PROSPECTS AND PROJECTIONS

Osborn, E. F.

Carnegie Inst, Washington, D. C.

Min. Eng. (NY) v26 n9 Sep 1974 p31-33

Abstract: To solve the energy crisis in this country, three basic energy criteria have to be met: abundance: reliability: and commercial availability by 1985. Only processes based on converting coal and oil shale to clean, synthetic fluid fuels can satisfy all three criteria. Several processes that are listed in the paper are already in advanced stages of development for converting coal to clean, synthetic gases, oils or both. Processes for low-Btu gas are briefly reviewed and the advantages of the in-situ gasification of coal are stressed. Estimated costs of clean, synthetic fluid fuels from coal are given. Future strategy outlook is discussed.

6.2.31

THEY'RE MAKING A SOLID EFFORT TO GET CLEAN COAL LIQUIDS

Burke, D. P.

Chemical Week 115/11/11/Sep 1974

p38-43

6.2.32

UOP ANNOUNCED PROCESS TO MAKE OIL FROM COAL

Eur. Chem. News 25/654/20 Sep 1974

Abstract: Universal Oil Products Co. has developed a process for making oil from coal. By the process, more than 4 barrels of a petroleum-like liquid can be produced from one ton of high-sulfur content coal. The process involves the mixing of pulverized coal with a solvent and hydrogen.

6.2.33

CONVERSION OF SOLID FUELS INTO OTHER ENERGY FORMS

Grainger, L.

National Coal Board

World Energy Conference, 9th Trans, Pap and Discuss. Detroit, Mich.
Sep 23-27 1974 v4 p162-183. Published by US National Comm of the
World Energy Conference, New York, 1975

Abstract: In European conditions, the first effect of the rise in oil prices relative to coal prices will be to improve the economics of using coal for the generation of electricity. Environmental consideration and the increasing requirement to improve the efficiency of conversion will favor the application of fluidized combustion and advanced cycles of electricity generation to the use of coal. Proposals for the next stage of development are outlined and the case is made for a national program and international cooperation on the problems which remain to be solved in order to allow coal to play its full part in providing energy in the quantities and forms required to meet the needs of the future. Data are presented in graphical form.

6.2.34

SYNTHETIC FUELS ACTIVITIES IN THE WESTERN HEMISPHERE

Swabb, L. E., Jr.

Exxon Res & Eng Co., New York, N.Y.

Dtsch Geg fuer Mineraloelwiss und Kihlechem, 24th Symp: Compend 74/75,
Hamburg, Germany Sep 30-Oct 3 1974 v1 p319-330. Published by Ind von
Hernhaussen (Erdoe) und Kohle Erdgas Petrochem, Suppl Leinfelden, Ger. 1975

Abstract: In the Western Hemisphere, there are large resources of coal, shale, tar sands and heavy crudes. Commercialization of the recovery of tar sands bitumen is underway. Large scale research and development efforts aimed at producing synthetic liquid and gaseous fuels from coal, shale and heavy crudes are progressing. The cost of synthetic fuels is expected to be comparable to other future energy supplies. This paper reviews synthetic fuels activities in the Western Hemisphere, including resources, technology and the properties and costs of the products.

6.2.35

COAL LIQUEFACTION

Friedman, S., Yavorsky, P. M., Akhtar, S., Wender, I.
US Bureau of Mines, Pittsburgh, Pa.
National Pet Refiners Assoc. Tech Pap for NPRA National Fuels and
Lubr Meeting, Houston, Texas Nov 6-8 1974 Pap F&L-74-55, 18p

Abstract: A general review and the status of coal liquefaction are given. The Synthoil process is described and such factors as reactor development, solids separation, pyrolysis of residues, and process costs are discussed in detail. 19 refs.

6.2.36

BOILER MODIFICATION COST SURVEY FOR SULFUR OXIDES CONTROL BY FUEL SUBSTITUTION. ENVIRONMENTAL PROTECTION TECHNOLOGY SERIES (FINAL)

Schreiber, R., Davis, A., Delacy, J., Chang, Y., Lockwood, H.
Acurex Corp., Mountain View, California Aerothern Div.
Contract EPA-68-02-1318
Nov 1974

Abstract: Results are presented of a study to identify capital costs associated with converting industrial and utility boilers from conventional high-sulfur fossil fuels to low-sulfur products from selected coal conversion processes. The boilers of concern include all industrial and utility size equipment in the 10 to the 7th power to 10 to the 10th power Btu/hr capacity range. The substitute fuels include solvent refined coal (SRC) in the solid and hot liquid (Melted) phases as well as lower-Btu gas, the cost assessment methods used in the study showed that conversion to liquid SRC is the most expensive alternative. Converting coal-fired boilers to solid SRC is the least expensive alternative for these types of boilers, between the costs of converting to SRC in either phase lie those costs for converting to the gaseous fuels. A significant result of the study is that the costs of all conversion strategies increase exponentially with boiler capacity: cost appears to be a weak function of boiler design.

NTIS PB-239455

6.2.37

FEDERAL ENERGY ADMINISTRATION PROJECT INDEPENDENCE BLUEPRINT FINAL
TASK FORCE REPORT: SYNTHETIC FUELS FROM COAL.

Annon

Federal Energy Administration, Washington, D. C.

Published by FEA, Washington, D. C.

Nov 1974, 182p.

Available from US Gov. Print Office (stock
n-4118-00010), Washington, D.C.

Abstract: This report provides the synthetic fuels data and information required for the Project Independence Blueprint evaluation. The data are the result of an examination of many processes for manufacturing fuel gas, liquid fuels and pipeline gas from coal, followed by the selection of representative processes in each category for detailed analysis. Estimates of capital investment and product cost levels were derived and are indicated. The probable impacts of plant construction and operation on local societies and government are presented. A summary of the areas of research and development which must be addressed prior to embarking on a plant construction program is presented. Various production scenarios are proposed.

6.2.38

SYNTHETIC FUELS FROM COAL R AND D PROGRAM

Mills, G. A.

Dept. of the Interior, Washington, D. C.

National Coal Board, Cheltenham, Eng. 1974

Second International Conference on Coal Research

Abstract: The synthetic fuels research effort is moving forward at an accelerated pace. Laboratory findings are being tested in several large pilot plants and definitive plans and commitments are being made for commercial-sized demonstration plants. An expanded and broad based program of supporting research is under way to ensure reliable operation and to search for significantly improved new processes. The overall objective is to provide the advance technology to rapid commercialization of processes for conversion of abundant coal resources to clean synthetic fuels in a manner environmentally acceptable and economically sound, there are several possible alternative strategies, namely: direct combustion with emissions control, coal liquefaction, high-Btu gas from coal and low Btu gas from coal. The R and D strategy is to pursue all of these technologies since all have significant potential for contributing to the alleviation of our energy problems and to the achievement of energy self-sufficiency. However, there is a significant difference in the emphasis and timing required. Earlier, high-Btu gas was given the most emphasis and
(cont'd)

funding, because natural gas was the most acute fuel shortage. Now the high-Btu gas program has reached the pilot plant stage, and with the recent shortage of petroleum products, the coal liquefaction program has become of major importance. The synthetic fuels program is directed to first supplement and then replace oil and natural gas on a massive scale. It has been assigned a number one priority because it can be relied upon to alleviate the energy crisis in both the short and mid-term period.

6.2.39

CLEAN FUELS FROM COAL

Bodie, W. W., Vyas, K. C.

Manage. Sc. Div., Inst. Gas Technology, Chicago, Ill.

Review with 68 refs 14 Coal Gasification or Hydrogasification Processes

9 Coal Liquefaction Processes

Oil Gas Journal 72/34/1974 p73-88

6.2.40

FULL-SCALE SOLVENT-REFINED-COAL PROJECT UNDERWAY - DEMONSTRATION PLANT

Chemical Engineering (NY) 82/2/20 Jan 1975

Abstract: Contracts have been signed between Gulf Oil Corp., the Southern Co., and Wheelabrator-Frye (an electric utility holding firm) covering a three phase project leading to construction of a 10,000 ton/day solvent refined coal plant. Projected cost for the first two phases is between \$70 million and \$100 million. If the demo plant operates successfully, it will be expanded to the 10,000 ton/day capacity under phase III at a projected cost of \$350 million.

6.2.41

SOLVENT REFINED COAL KEEPS FLUE GAS CLEAN

Jimeson, R. M.

Chem. Eng. (NY) 83/5/1 Mar 1975 p 80-81

6.2.42

STATUS OF THE SRC PROJECT

Schmid, B. K.

Pittsburg and Midway Coal Mining Co., Ft. Lewis, Va.

Chem. Eng. Pro. 71/4/ Apr 1975

p75-78

6.2.43

WORLD COAL RESEARCH: PART 2

Bagge, C. E.

World Coal 1/2 Apr 1975

p20-3

6.2.44

OVERSEAS RESEARCH ON THE PRODUCTION OF OIL FROM COAL. REPORT NO. 4

New Zealand Energy Research & Development Committee, Auckland (4670300)

Walker, B. V.

Apr 75 34p

Monitor: 18

Available from ERDA, P.O. Box 62, Oak Ridge, Tn. 37830, Attn: TIC.

Abstract: This is a report of the results of overseas travel carried out between 12 October and 5 December 1974. The primary objective was to assess current developments in 'oil from coal' technology and their applicability to New Zealand conditions. This assessment is being used to determine the extent of future New Zealand research in the field of 'oil from coal'. The status of the various liquefaction processes is summarized and recommendations for New Zealand research activity are given. Details of liquefaction technology, engineering problems and economics and notes of visits to various research establishments are given. The net result is a rather good summary of the status of the various processes and of coal liquefaction research in the various countries visited as of this date. (ERA citation 92:008959)

NTIS NP-21120

6.2.45

SOLVENT REFINED COAL

Huffman, E. L.

Combustion 46/11 May 1975 28-29

6.2.46

OVERVIEW OF COAL LIQUEFACTION PROJECTS

Friedman, S., Akhtar, S., Yavorsky, P. M.

Energy Research and Development Administration, Grand Forks, N. Dakota

Grand Forks Energy Research Center

Energy Research and Development Administration, Pittsburgh, Pa. 1975

6.2.47

TECHNOLOGY AND USE OF LIGNITE

Kube, W. R., Gronhøvd, G. H.

Symposium on Technology and Use of Lignite

Grand Forks, N. Dakota

14 May 1975

Abstract: The dual objectives of the government's coal liquefaction development program are, in order of priority, production of low-sulfur, low-ash fuel oil for generating electricity without pollution, and production of upgraded products as gasoline, turbine fuel, and petrochemical feedstocks, the synthetic fuel oil is the easiest and cheapest product to make, and would replace petroleum products and natural gas burned for power, eliminating the need for mideast imports of oil and gas. Current
(cont'd)

work is reviewed for these four categories of coal liquefaction projects: (1) direct hydroliquefaction includes the Synthoil, H-coal, zinc chloride, disposable catalyst, and CO-steam processes, differing in reactor style and/or choice of catalyst, (2) solvent extraction includes two similar pilot plants. The SRC process by Pittsburgh-Midway Coal Company (OCR) and another by Southern Services, differing somewhat in extraction conditions and size, (3) carbonization includes COED, clean coke, and hydrocarbonization processes, involving different schemes to upgrade or extend liquid yield by use of byproduct hydrogen from carbonization or char gasification, (4) indirect liquefaction involves converting coal to syn-gas ($\text{CO} + \text{H}_2$) first, followed by catalytic recombination to methanol fuels. Liquid hydrocarbons and possibly ethylene as chemical feed stock. Projects in this category are not yet underway. Higher costs of this route may be justified by higher values of specialized products.

6.2.48

SYNTHETIC GAS AND LIQUID FUELS FROM COAL

Teck, M. R.

University of Michigan, Ann Arbor

Energy Commun. v1 n5 1975 p495-523

Abstract: As related to immediate and longer range energy needs, coal remains a major focal point of interest as a lasting resource to supplement imminent deficiencies in our domestic natural gas and crude oil reserves. Current technology, present research and future potential of coal conversion are reviewed with particular emphasis of engineering, environmental, and economic feasibility.

6.2.49

RESEARCH STUDY ON ISSUES RELATIVE TO THE DEVELOPMENT AND COMMERCIALIZATION OF A COAL-DERIVED SYNTHETIC LIQUIDS INDUSTRY. QUARTERLY REPORT, MARCH 1976-JUNE 1975

Hudson Institute, Inc., Croton-on-Hudson, N.Y.

Candela, B. J.

July 75 21 p

Abstract: United States dependence upon oil imports may increase to very substantial levels unless US demand can be satisfied from domestic production. In order that the Nation's abundant coal resources can be substituted for important oil products, it appears necessary to develop, as rapidly as possible, a coal-derived synthetic oil industry and to introduce its products progressively into the energy mix. Planning for large-scale production of synthetic oils from coal must relate to political, economic, environmental, legal, and other considerations. Hudson Institute is to study and analyze issues relevant to the creation and recommendations relating to this objective. A Final Report is to be issued in February of 1976 except for energy consumption projects which were presented in June of this year.

NTIS FE-1752-6

6.2.50
OPTIMISM PREVAILS FOR SOLVENT REFINING

Deppe, W. L.
Catalytic, Inc., Wilsonville, Al.
Pittsburg and Midway Coal Mining Co. (PAMCO) Technology
Coal Min. Process. 12/8 Aug 1975
48-50/62-63

6.2.51
OVERVIEW OF R AND D ON COAL LIQUEFACTION

Yavorsky, P. M.
Pittsburgh Energy Research Center
University of Pittsburgh, Pittsburgh, 1975
Second Annual Symposium on Coal Gasification, Liquefaction, and Utiliza-
tion: Best Prospects for Commercialization
Annual Symposium on Coal Gasification, Liquefaction and Utilization best
Prospects for Commercialization, Pitts, Pa. 1975 (Aug 5)

Abstract: Various methods of coal liquefaction are described briefly,
in general, the methods described are: direct catalytic hydrogenation,
solvent extraction, pyrolysis, and indirect variations. Flowsheets for
several of the processes are included.

6.2.52
TECHNICAL AND ECONOMIC FEASIBILITY OF SOME ALTERNATIVE FUELS FOR
AUTOMATIVE TRANSPORTATION

Gillis, J. C., Pangborn, J. B., Vyas, K. C.
Inst. of Gas Tech., Chicago
Inst. of Electrical and Electronics Engineers, Inc., New York 1975
Tenth Intersociety Energy Conversion on Engineering Conference

6.2.53
DECISION MAKING FOR SYNTHETIC FUELS

Dickson, E. M.
Stanford Res Inst, Menlo Park, California
Intersoc Energy Convers Eng Conf. 10th. Rec, University of Delaware
Newart, Aug 18-22 1975 Pap 759101 P651-657 Published by IEEE, New York 1975

Abstract: For most new product offerings the manufacturer is properly
concerned with obtaining an estimate of the share of the market that his
new product may capture. In Stanford Research Institutes' impact study
of synthetic liquid fuels produced from coal and oil shale resources,
therefore, it would seem appropriate to ask what fraction of the consumer
market gasoline produced from oil shale, for example, might ultimately
capture. However, discussions with energy industry experts and stakeholders
have revealed that the question of market penetration of the final consumer
product is less fundamental to the impact study than is the question of
how and why decisions to deploy synthetic liquid fuel production technologies
will be made. 4 refs.

6.2.54

COAL CONVERSION TECHNOLOGIES

Illinois State Dept. of Business and Economic Development, Springfield
Division of Energy; National Science Foundation, Washington, D. C. Office
for the International Decade of Ocean Exploration.

Final Report

Grandys, K.

1 Sep 75 34p

Monitor: NSF/IDOE-75-04

Abstract: This report gives the reader a brief overview of the most promising technologies in the fields of coal gasification and liquifaction.

NTIS PB-260 664/8ST

6.2.55

KENTUCKY ENERGY RESOURCE UTILIZATION PROGRAM

Kentucky Univ., Lexington Inst. for Mining and Minerals Research

Quarterly Progress Rept. 1 Apr-30 June 1975

Sept '75 39 p

Rept. No. IMMR5-PR1-75

Abstract: This report describes progress on the Kentucky Energy Resource Utilization Program during the three-month period ending June 30, 1975. The projects are grouped into the areas of Mining, including manpower development and technological projects, Process Development which includes studies on gasification and liquefaction and the improvement of ancillary processes associated with these operations, and Geology and Reserves which includes projects aimed at accelerating the evaluation of the Kentucky coal reserves and projects in reclamation and environmental effects.

NTIS PE-250 687/1ST

6.2.56

COAL GASIFICATION AND LIQUEFACTION

Huebler, J.

Institute of Gas Technology, Chicago, Ill

1975

Mining Convention Exposition, Session of Western Coal Mining

San Francisco, California

30 Sep 1975

Abstract: There is a critical need to establish a coal conversion industry in the shortest possible time. Commercially proved processes are available to convert coal to pipeline-quality gas for use by the natural gas industry or to lower Btu gas for use by electric utilities and manufacturing industries, at least one second-generation process (HYGAS) is ready for demonstration at the commercial scale. Commercially proved processes for liquid production exist for methanol, and the Fischer-Tropsch process is available for hydrocarbon production, but these processes are very expensive. Production of liquids by pyrolysis or dissolution requires extensive development and demonstration on a large scale. The cost of all these coal conversion products is well above the costs of their natural counterparts, including imported oil. Even though positive governmental action has been adequate in supporting the development of new, less expensive technology, the Federal Government has been totally indecisive in solving political and regulatory problems needed to launch an industry.

6.2.57

ALTERNATE UTILITY FUELS FROM COAL

Parker, J. D.

Oklahoma State Univ., Stillwater

1975

Conference on Frontiers of Power nechnology

Stillwater, Oklahoma

1 Oct 1975

Abstract: It appears that it is technologically feasible to manufacture gas or liquid fuels from coal. Commercially proven processes have been developed and better, second generation processes are being tested and proven. Electric utilities should benefit mostly from developments in low-Btu gasification for use in coal conversion processes with combined cycles. Mixing of low-Btu fuel with natural gas might be a desirable way to stretch present fuel supplies. Liquid fuels from coals are particularly appealing because of their storage and transport capabilities.

6.2. 58

GASIFICATION AND LIQUEFACTION OF COAL

Huebler, J.

Short Surveys of various processes

Min. Congr. Journal 61/10 Oct 1975

16-23

6.2.59

SOLVENT REFINED COAL IN JAPAN: PAST AND PRESENT

Baba, A.

Chem. Econ. Eng. Rev. 7/10 Oct 1975

15-19

Abstract: After describing uses for products of coal solvent refining processes, the author discusses the Japanese fuel research institute process, which is the only solvent refining process operated industrially in Japan, and gives details of the Hiragishi Plant. The present position in this field in Japan is briefly summarized.

6.2.60

EXPERIENCE IN THE FIELD OF HYDROGENATION OF POLISH COALS

Malecki, B.

Przegl. Gorn. 31/10 Oct 1975

415-420

Abstract: Work on coal liquefaction being carried out in a large laboratory plant at the Polish Central Mining Institute is described. The processes of coal extraction, filtration, low temperature carbonization of the residue hydrogenation of extracts and hydrogenation of anthracene oil are all discussed.

6.2.61

COAL PROCESSING AND UTILIZATION, II, SA COAL SET FOR GLORIOUS FUTURE

Horsfall, D. W.

Coal, Gold Base Miner. South Africa 23/10/Dec 1975

49, 51, 53, 55, 57

Abstract: Coal in South Africa seems to be set for a glorious future-- the need for coal-based energy is indisputable, and abundant coal reserves are likely to be available. The only question is whether the present level of research effort, bearing in mind the extremely diverse nature of coal applications, is adequate. The extent of work at universities, which are in training grounds for tomorrow's coal experts, is limited. No University, for example, has a "Coalschool" as such. The University of Cape Town's utilisation unit is a particularly noteworthy organization in this respect, and work on a different scale, is being carried out at the University of the Witwatersrand, where projects to show the needs of the various energy-consuming sectors, and how the available resources can best be deployed to meet those needs, are being developed as on-going student projects.

6.2.62

ROBENS COAL SCIENCE LECTURE, 1975: THE COAL RENAISSANCE - A SOUTH AFRICAN POINT OF VIEW

Rousseau, P. E.

South African Coal Oil and Gas Co., LTD. (SASOL)

J. Inst. Fuel 48/397/Dec 1975 p 167-75

6.2.63

RECOMMENDATIONS FOR A SYNTHETIC FUELS COMMERCIALIZATION PROGRAM, VOLUME 1: OVERVIEW REPORT, (VOLUME 2: COST/BENEFITS ANALYSIS OF ALTERNATIVE PRODUCTION LEVELS, VOLUME 3: TECHNOLOGY AND RECOMMENDED INCENTIVES, VOLUME 4: DRAFT ENVIRONMENTAL IMPACT STATEMENT, ERDA-1547) 1975

Anon

US Energy Resource Council, Washington, D.C.

Recommended for a Synthetic Fuels Commer. Program Prepared by Synfuels Interagency Task Force for the Pres. Energy Resource Council, Washington, D. C., 1975, 4 vol. Available from Supt of Doc, US Gov Print Office, Washington, D.C.

Abstract: This report evaluates alternatives for accelerating the commercialization of synthetic fuels technology in the United States and recommends a program of appropriate size and scope. Also provided are recommendations concerning measures needed for program initiation and implementation. An incentive program for Synthetic Fuels Commercialization was proposed by the President in 1975 to support a goal of developing an equivalent of 1 million b/d of synthetic fuels by 1985 from coal and oil shale. The results of an Interagency Task Force's efforts to examine alternatives for implementing the President's goal are summarized in Volume I of this report, and are described in detail in Volumes II, III, and IV.

6.2.64

RECOMMENDATIONS FOR A SYNTHETIC FUELS COMMERCIALIZATION PROGRAM. VOLUME II. COST/BENEFIT ANALYSIS OF ALTERNATE PRODUCTION LEVELS

Interagency Task Force on Synthetic Fuels, Washington, D.C. Federal Energy Administration, Washington, D.C. Energy Research and Development Administration, Washington, D.C. Office of Commercialization. Energy Resources Council, Washington, D.C.

Nov 75 362p

Monitor: FEA/B-76/047

Prepared in cooperation with Energy Research and Development Administration, Washington, D.C. Office of Commercialization, and Energy Resources Council, Washington, D.C.

Abstract: This report examines alternatives for implementing the President's goal of assuring early commercialization of synthetic fuels in the United States. The cost/benefit analysis addressed the question of whether the
(cont'd)

Federal Government should accelerate the commercial production of synthetic fuels and, if so, at what rate. Specifically, the alternative program levels evaluated in this report are: (1) No Program - no Federal involvement in a commercialization program, but continuation of research and development and normal investment decisions by U.S. industry, (2) Information Program - Federal involvement designed to assist in the establishment of the equivalent of 350,000 barrels per day in capacity, (3) Medium Program - designed to produce approximately 1,000,000 barrels per day, (4) Maximum Program - designed to produce approximately 1,700,000 barrels per day.

NTIS PB-249 446/6ST

6.2.65

RECOMMENDATIONS FOR A SYNTHETIC FUELS COMMERCIALIZATION PROGRAM, VOLUME III
TECHNOLOGY AND RECOMMENDED INCENTIVES

Interagency Task Force on Synthetic Fuels, Washington, D.C. Federal Energy Administration, Washington, D.C. Energy Research and Development Administration, Washington, D.C. Office of Commercialization. Energy Resources Council, Washington, D. C.

Nov 75 982p

Monitor: FEA/B-76/048

Prepared in cooperation with Energy Research and Development Administration, Washington, D. C. Office of Commercialization and Energy Resources Council, Washington, D. C.

Abstract: This report presents the technology and incentives recommended to establish a commercially viable Synthetic Fuels Commercialization Program (SCP) directed toward achieving the President's goal of one million barrels of crude oil equivalent per day in 1985. Analysis of each incentive considers its ability to meet the following criteria: effectiveness, competitiveness, administrative feasibility, federal involvement, flexibility, breadth of participation, existing authority, and contingency analyses. Availability of energy producing raw materials such as coal, shale, and biomass waste and the market for synthetic fuels are covered. Portions of this report are not fully legible.

NTIS PB-249 447/4ST

6.2.66

RANN UTILIZATION EXPERIENCE. CASE STUDY NO 19. SOLVENT REFINED COAL

Research Triangle Inst., Research Triangle Park, N.C.
National Science Foundation, Washington, D.C. Research Applied to
National Needs. Auburn Univ., Ala (304 400)

Taylor, Z. L.

1975 22p

Grant: NSF-C927

Monitor: NSF/RA/G-75-047

Also included in complete report and summary, PB-247 243

In cooperation with Auburn Univ., Ala.

Abstract: Coal, America's most abundant and available natural fuel source, can contribute significantly to supplying the nation's increasing demand for fuels if improved extraction and refining technologies can be developed that meet anti-pollution requirements. This project investigated one process for coal gasification and liquefaction. The primary product of the solvent refined coal (SRC) process is a solid fuel from which the impurities and inflammable materials have been removed. The report briefly reviews use of the research results.

NTIS PB-247 262/9St

6.2.67

U. S. COAL

Hendrickson, T. A. (COMP)

Data on types of coal found and conversion to synthetic gaseous, liquid and solid fuels, origin of coal

Cameron Engineers, Inc., Denver 1975

Synthetic Fuels Data Handbook

6.2.68

COAL LIQUEFACTION

Bureau of Mines, Pittsburgh, Pa. (1016000)

Friedman, S., Yavorsky, P. M., Akhtar, S., Wender, I.

19p

Monitor: 18

Abstract: The first portion of this report is a general review and status of coal liquefaction dealing with direct hydrogenation, extract hydrogenation, pyrolysis, and a coal liquefaction demonstration plant. The second portion is a discussion of the Synthoil process for clean fuel oil from coal.

NTIS CONF-741146-1

6.2.69
REVIEW OF COAL CONVERSION TECHNOLOGY

Oak Ridge National Lab., Tenn. (4832000)
Pickel, T. W.
1975 13p
Monitor: 18

Abstract: An outline of the presentation and representations of the slides used are given. The introduction covered the goals of the program, the history of coal conversion, and orientation numbers to illustrate the magnitude of the problem. Coal gasification was described by means of a flowsheet. Coal liquefaction was covered under the headings: solvent refined coal, hydrocarbonization, direct hydrogenation, solvent extraction-hydrogen donor, comparison of processes, and development areas. A comparison of some coal liquefaction processes is presented in tabular form.

NTIS CONF-751035-1

6.2.70
SOLVENT REFINED COAL PROCESS FOR "CLEAN" UTILITY FUEL

Shaver, R. G.
General Tech. Corp., Reston, Va.
American Chemical Society, Div. Fuel Chem., Prepr. 17/2/1976
27-35
164th National American Chemical Society Meeting
New York, N.Y.
27 Aug 1972

Abstract: The continued wide use of coal in the United States as a fossil-fuel source of combustion energy for power generation is inescapable in the upcoming decade and beyond, several processes exist at various stages of development for producing clean fuels from raw coal. Solvent refining is a relatively simple and direct way of deashing and desulfurizing coal that results in fuel products usable as solid or liquid, making it applicable to either coal-fired or oil-fired steam-electric utilities. The projected economics of production and distribution for such use are presented taking no credits for sale of the sulfur by-product and considering production solely for the use of the utilities. As a clean fuel, solvent refined coal is found to be potentially competitive with desulfurized residual oil, and in many instances, a potentially more economical way to use coal than by gasification. The projected market in the continental United States for solvent refined coal over the range of expected fuel price in the future under clean fuel restrictions is estimated.

6.2.71

RESEARCH STUDY OF ISSUES RELATIVE TO THE DEVELOPMENT AND COMMERCIALIZATION
OF A COAL-DERIVED SYNTHETIC LIQUIDS INDUSTRY.
QUARTERLY REPORT, October 1975-December 1975

Hudson Institute, Inc., Croton-on-Hudson, N.Y.
Energy Research and Development Administration
Candela, B. J.
Feb 76 20 p

Abstract: The demand for liquid fuels is forecast for 10, 25 and 50 years in the future and various strategies are suggested. One big problem in choosing between these strategies is what will be the future price of Arab oil. As a result of arguments given, this price is expected to rise slowly from the present \$11/barrel, but three different price scenarios with time are developed. Possible financial incentives for coal liquefaction plants are considered and related to proposed nuclear fuels legislation under consideration (as a method of predicting presidential and congressional approach). Finally, certain technical problems are discussed: Labor requirements (special skills), socio-economic factors (local impacts of plants), planning, water availability (discussed with respect to regional areas), environmental effects (including cost of meeting state and federal standards), and economics (interest rate, size of program, risk, effects on other projects, necessity of financial incentives or guaranteed prices, etc.)

NTIS FE-1752-11

6.2.72

CLEAN FUELS FOR COAL CONVERSION

Merrill, Robert C.
COGAS Dev. Co., Princeton, NJ
J. Ashes Sealant Counc. v4 n 1, Spring 1976. Energy Changes - A Challenge to Industry, Spring Seminar, Philadelphia, Pa. Mar 1-3, 1976 p 26-4

Abstract: This paper presents a status report on the more well-known coal conversion processes which have been developed for the production of synthetic crude oil (synthetic liquid fuel) and substitute natural gas from coal and lignite. There are presently three commercially available coal gasification processes. Numerous second-generation coal conversion processes are under development, some of which should be ready for commercialization by the early 1980's. However, with today's uncertainties over future coal, oil and gas prices and rapidly escalating plant costs, the future for coal conversion is not at all certain. Government assistance in many areas is needed if clean fuels from coal conversion are to become a reality. 3 refs.

6.2.73

SOLVENT-REFINED COAL KEEPS FLUE GAS CLEAN

Jimeson, R. M.

Chem. Eng. (NY) 83/6/1/Mar 1976

Abstract: The use of low-sulfur, low-ash solvent-refined coal, is especially appropriate for users of small or medium-size boilers. Use of this coal avoids the capital cost of a flue gas desulphurization system, and prevents possible shut-downs because of failures in the scrubbing system. The solvent-refined coal process is described. The hot solvent-refined coal produced can be burned in an adjacent power plant, or can be cooled for subsequent handling and shipping. It can be hydrocracked and reformed to convert it to light and heavy distillates or a synthetic crude oil. The cost of the solvent-refining process is estimated to be about \$22 per ton of refined coal.

6.2.74

OIL AND GAS FROM COAL

Cochran, N. P.

Scientific American 234/5 May 1976

24-29

Abstract: Conversion can be accomplished by several tested processes. The present effort is to combine such processes in a large-scale system that will manufacture the oil and gas at reasonable cost. A plant making oil and gas from coal must be located at the mine otherwise the cost of moving from 25,000 to 100,000 tons of coal per day would make the plant uneconomical. Coal varies considerably from one area to another, and energy markets also vary from region to region, for example, in the Appalachian region the coal is bituminous and high in volatiles on the northern great plains it is lignite. The coal refinery described, combining extraction, hydrogenation, and Fischer--Tropsch synthesis can be adapted to fit the characteristics of any coal, and the mixture of products can be adjusted to any market, to achieve a capacity of a million barrels per day of synthetic fuel calls for a vigorous government program. The creation of a synthetic-oil industry would assure the nation of ample supplies of oil and gas. Moreover, the synthetic fuels would act as a ceiling on the price of crude oil from abroad. At the same time the country would have the assurance that it was no longer dependent on foreign supplies of oil.

6.2.75
ENERGY FROM COAL

Fumich, G. Jr.
Energy Research and Development Administration, Washington, D. C.
Combustion 47/11 May 1976
7-14

Abstract: U.S. ERDA's Research programs (and the strategy and goals involved) for coal gasification, coal liquefaction, direct coal combustion, and advanced power cycles (combined cycles, magnetohydrodynamics) are reviewed briefly. Technical management and coordination of the program and industry - government cooperation are discussed.

6.2.76
SOLVENT REFINED COAL FOR POWER GENERATION

Harrison, W. B.
Combustion 47/11 May 1976
20-22
Joint Power Conference
Portland, Or.
28 Sep 1975

Abstract: The Southern Company is trying to determine if solvent-refined coal, which is desulfurized in the processing, represents a viable alternative to burning high sulfur coal and desulfurizing the stack gases, flowsheets and processing conditions are given as presently determined, the main effort at present is to improve the quality of the data so the relationships between operating variables, product quality and yields can be determined more precisely.

6.2.77
COAL CONVERSION R & D: WHAT THE GOVERNMENT IS DOING.

Zahradnik, Raymond L.
ERDA, Washington, DC
Chem Eng Prog v 27 n 6 June 1976 p 25-32

Abstract: A description is presented of work currently being carried out in the following areas: liquefaction, high Btu gasification, low Btu gasification, power and combustion, and demonstration plants.

6.2.78

REVIEW OF COAL LIQUEFACTION RESEARCH WORK IN THE UNITED STATES (COAL LIQUEFACTION DEVELOPMENT AND ENVIRONMENTAL REGULATION).

Wolk, Ronald H.

Electric Power & Research Inst. Palo Alto, Calif

Sampling Strategy and Characteristics of Potential Emissions from Synfuel Prod. Symp/Workshop, Proc., Austin, Tex. June 8-10 1976

Publ by ERDA (CONF-760602), Washington DC, 1976. Available from NTIS Springfield, Va p26-42

Abstract: This paper summarizes results of R&D works carried out in the United States to develop commercial method for the production of synthetic liquid fuel from coal. In this connection, the environmental impact of new technologies is considered in terms of existing legislations. The discussion is presented under headings EM- rationale for commercial coal liquefaction, potential uses of coal liquids; technical status of liquefaction, potential uses of coal liquids; technical status of liquefaction R&D; present environmental rules for coal conversion plants; special problems associated with coal liquids; special design problems and approaches for coal liquefaction plants; in-plant health control measures; sampling of process streams; control strategies for effluents; effects of standards on process development.

6.2.79

SYNTHETIC FUELS FROM COAL AND OIL SHALE (TECHNOLOGICAL AND ECONOMIC ASSESSMENT)

Vyas, K. C., Ashworth, R. A., Barnett, F. M.

Arthur G. McKee & Co., Cleveland, Ohio

ASME Pap n76-Pet-22 for Meet Sep 19-24 1976, 11p

Abstract: An overview of coal and oil shale conversion is presented in this paper. General aspects of gasification and liquefaction processes and the variables affecting them, as well as the environmental aspects, efficiencies, and economics comparison of the various conversion routes are discussed. 9refs.

6.2.80

OVERVIEW OF THE GOVERNMENT'S PROGRAMS IN COAL CONVERSION, RESEARCH
AND DEVELOPMENT

Zahradnik, R. L.

Energy Res & Dev Administration, Washington, D. C.

ASME Pap n76-PVP-16 for Meeting Sept 19-24 1976, 8p

Abstract: The Federal Government is currently sponsoring a large effort of Research and Development in coal conversion and utilization. This effort is cost-shared with private industry to a significant extent and is directed toward the establishment of a viable coal conversion industry in the United States by the mid 1980's. The program plans, current activities and achievements, future directions, and funding levels are discussed.

6.2.81

COAL POWER AND COMBUSTION, QUARTERLY REPORT, OCTOBER -- DECEMBER 1975

Energy Research and Development Administration, Washington, D.C.

Office of Fossil Energy 1976

Abstract: Progress in US ERDA's Research and Development Programs in fluidized-bed combustion is reported. This involves the 30 MW atmospheric pressure fluidized-bed boiler at Rivesville, Va. (which is almost ready to operate), pressurized fluidized-bed combustion experiments in pilot plants and MIUS (ORNL'S modular integrated utility system). Other work in this program involves combustion of coal-oil slurries, combustion of solvent-refined coal, combustion of anthracite wastes (by fluidized combustion), high temperature dust control, applications of fluidized-bed combustion to industrial boilers and supporting planning, technical and engineering services.

NTIS- ERDA-76-31-4

6.2.32

CLEAN ENERGY FROM ALASKAN COALS. FINAL REPORT, JANUARY 1974--DECEMBER 1975

Stanford Research Inst., Menlo Park, Calif., Energy Research and

Development Administration (5911000)

1976 191p

Contract: E(49-18)-1516

Monitor: 18

Abstract: This study was undertaken to determine if one of the processes for conversion of coal to clean fuels--the solvent-refined coal (SRC) process--could be used as a means of economically producing clean energy from coal deposits located in remote areas. Alaskan coals, specifically the Beluga coal fields, were selected as a hypothetical example because this vast resource base has been virtually untapped. Preliminary cost estimates were prepared for coal mining, coal conversion, and product transportation to Pacific fuels markets. Based on the assumptions used
(cont'd)

and on the economics developed, the cost of a solvent-refined coal product will probably be significantly more expensive than alternate fuels (chiefly oil). For this primary reason, little penetration of Alaskan solvent-refined coal into Pacific fuels markets is forecast. A potential market may exist for Beluga coal. On the U.S. West Coast, delivered prices for this low-sulfur fuel are estimated to fall within the competitive price range for alternative low-sulfur western coals.

NTIS FE-1516-2

6.2.83

1976 KEYSTONE COAL INDUSTRY MANUAL

Nielsen, G. F. (ed)
McGraw-Hill, Inc., New York 1976

Abstract: The manual is the industry reference authority for the many diverse organizations concerned with the supply and utilization of coal in the United States and Canada. For its many other users as well Keystone serves as a comprehensive reference to the production and distribution facilities of the coal industry and is the source of considerable data unavailable elsewhere. Some new features in the 1976 edition are: coal research projects in mining and preparation. The laboratory's role in the coal industry. New concepts requiring pollution controls. A 1975 review of scrubbers, a portfolio of preparation flow-sheets, growth of the industrial market, slurry pipeline planning, a new mining capacity survey, a map of 1974 coal production by counties and a complete listing of smaller coal mining companies.

6.2.84

CAN FUEL PROCESSING COMPETE WITH FLUE GAS PROCESSING?

Harrison, W. B.
South Serv Inc, Birmingham, Ala.
ASME Air Pollution Control Div., 4th National Symp: Ambient Air Quality Stand. -- Here We Are, What Do We Do? St. Louis, Mo, Mar 24-25 1975 p211-230. Published by ASME, New York, NY 1976

Abstract: The paper discusses various aspects of the choice between fuel processing and flue gas processing in connection with cost-effective generation of electricity in compliance with environmental regulations. Alternatives for fuel processing, such as coal gasification, and for flue gas processing are outlined and weighed against air quality requirements.

6.2.85

IMPACT OF COAL AND OIL SHALE PRODUCTS ON GASOLINE COMPOSITION - 1976-2000.
TASK ONE

Southwest Research Inst., San Antonio, Tex. Mobile Energy Div.
Environmental Protection Agency, Ann Arbor, Mich. Emission Control Tech. Div.
Final Rept. 1 Feb-Dec 76

Newman, F. M., Russell, J. A., Bosden, J. N., Johnson, A. A.

Dec 76 41 p

Contract: EPA-68-03-2377

Monitor: EPA/460/3-76/035

Report on Identification of Emissions from Gasolines Derived from Coal and Oil Shale.

Abstract: A consensus assessment is made of the impact of coal-and oil shale-derived crudes upon the composition of gasoline. It is concluded that this impact will be negligible, since the most promising area for utilization of such crudes will be as burner fuels and middle distillates. Such utilization of coal and oil shale resources will, in turn, reduce the demand on petroleum resources which will continue to be the principal source of gasoline for the remainder of the 20th century.

NTIS PB-265 478/8ST

6.2.86

IMPACTS OF SYNTHETIC LIQUID FUEL DEVELOPMENT -- ASSESSMENT OF CRITICAL FACTORS,
VOLUME 1: SUMMARY AND VOLUME 2: ANALYSIS

Dickson, Edward M.; Steele, Robert V.; Hughes, Evan E.; Walton, Barry L.;
Zink, R. Allen; Miller, Peter D.; Ryan, John W.; Simmon, Patricia B.;
Holt, Buford; White, Ronald K.; Harvey, Ernest C.; Cooper, Ronald;
Stoneman, Ward C.; Phillips, David F.
Standard Research Inst., Menlo Park, Calif.

Impacts of Synth Liq Fuel Dev -- Assess of Crit Impacts of Synth Liq Fuel Dev --
Assess of Crit Factors Prepared for ERDA, Div. of Transp Energy Conserv (ERDA
76-129/1: 129/2), Washington, D.C., and EPA, Off of Res and Dev (EPA 600/7-76-
004A; 004B), Washington, DC by Stanford Res Inst. Available from GPO 2 vol,
970 p.

Abstract: This book contains documents which report the results of a technology assessment of selected liquid fuels derived from coal and oil shale. These fuels are considered to be the most likely alternatives to substitute for or augment petroleum-derived fuels in the transportation sector in the 1980-2000 time frame. The report is divided into two volumes. The first volume consists of an executive summary and a detailed analyses of various aspects of the development of a synthetic liquid fuels industry. Each chapter in Volume II has its own literature citations. This study examines many dimensions of anticipated impact from coal liquefaction and oil shell processing technologies -- environmental, economic, social, and energy flow.

6.2.87

IS COMMERCIAL COAL CONVERSION PRACTICAL?

Anon

Energy (Stamford Conn) v2 n 1, Winter 1977 p 16-19

Abstract: Increasing capital costs and price uncertainties have resulted in plant postponements. ERDA's loan guarantee proposals which would have guaranteed \$4 to \$6 billion for synthetic fuels, renewable energy sources and energy conservation projects also died. Liquefaction and gasification capital requirements, technical risks, coal availability, water availability, and other problems are discussed.

6.2.88

PETROCHEMICAL FEEDSTOCKS FROM COAL.

O'Hara, J. B.; Becker, E.D.; Jentz, N.E.' Harding, T.

Ralph M. Parsons Co., Pasadena, Calif

Chem Eng Prog v 73 n 6 June 1977 p 67-72

Abstract: This paper discusses the possibility of substitution of coal conversion products for naphtha-gas oil range as feeds for the manufacture of petrochemical hydrocarbons. It is demonstrated that the introduction of coal conversion as an important feedstock supplier could affect the future structure of the petrochemical industry. This article suggests ways in which coal conversion plus supporting process steps can be used to supply petrochemical feedstocks and petrochemicals. During hydroliquefaction coal conversions, light hydrocarbons and aromatic-rich liquids are produced and can be processed to yield desirable feedstocks. Fischer-Tropsch conversion can also be made to produce light hydrocarbons, and in this case, heavier liquids that are aliphatic in nature. Projected yield structures have been presented, and a conceptual complex is described which uses these products to produce ethylene, BTX, and a number of fuel and chemical products. Results of preliminary analysis work to date provide a base for more detailed technical and economic analysis of this potentially important extension of the results of the current national priority ERDA-sponsored fuels-from-coal development program. 21 refs.

6.3 SOLIDS SEPARATION

Even though solids separation is a major problem in the SRC process, surprisingly very few publications have been available on the subject. The main sources of these papers are Oak Ridge National Laboratory, Lummus Company, Abcor, Inc. and University of Michigan. There is a large effort going on in solids separation at various pilot plants. Details of these efforts are scattered in various periodic reports published by the operators of these plants. Publications cover filtration equipment, development and solvent deashing techniques. Reports from Wilsonville (See Appendix 12) describe the operation of Funda filters as well as hydroclones and centrifuges. Reports from Fort Lewis (See Appendix 13) include the rotary drum filter operation.

6.3.1

SOLVATION AND HYDROGENATION OF COAL IN PARTIALLY HYDROGENATED HYDROCARBON SOLVENTS.

Inventors: William M. Leaders; Jack W. Roach.

Appl No.: 1,689

Filed: Jan 9, 1970

Patented: Sept. 21, 1971

Assignee: Kerr-McGee Corporation, Oklahoma City, Okla.

Patent No.: 3,607,718

Abstract: Coal is solubilized and hydrogenated in partially hydrogenated hydrocarbon streams such as clarified slurry oil to produce a nonviscous solution which is readily deashed by settling or filtering. Both inorganic sulfur and organically combined sulfur are removed, and the deashed solubilized coal thus produced has a very low sulfur content. The invention is also useful for producing a hydrogenated solubilized coal solution which is suitable for use as a feedstock for a petroleum refinery, and valuable liquid hydrocarbon distillate products boiling, for example, within the gasoline, kerosene, naphtha, light fuel oil and gas oil ranges may be produced therefrom.

6.3.2

FRACTIONATING COAL LIQUEFACTION PRODUCTS WITH LIGHT ORGANIC SOLVENTS

Inventor: Jack W. Roach

Appl No.: 1,818

Filed: Jan 9, 1970

Patented: Sept. 21, 1971

Assignee: Kerr-McGee Corporation, Oklahoma City, Okla.

Patent No.: 3,607,717

Abstract: Coal liquefaction products are separated into a plurality of fractions of varying softening points and molecular complexity by treatment with light-organic solvents having critical temperatures below 800°F under elevated temperature and pressure conditions. In one variant, coal is liquefied employing selected light organic solvents which are suitable for both liquefaction and fractionation, and thereafter the coal liquefaction products are separated into a plurality of fractions by treatment with the solvent contained in the resultant solution. Preferred solvents for liquefying coal include pyridine and benzene, and preferred fractionating solvents include pyridine, benzene and hexane. In a preferred variant, a solvent phase is recovered directly from the final fractionating stage and is passed in heat exchange relationship with solvent-rich streams to preceding fractionating stages to recover the heat content and provide cooled solvent for recycle. The invention further provides a method of separating finely-divided insoluble material derived from coal during liquefaction thereof from an organic-solvent solution of coal liquefaction products.

6.3.3

CONVERSION OF COAL TO CLEAN FUEL

Everett Gorin, et al.

Patent No. 3,791,956

Date: Feb. 12, 1974

Abstract: Production of a low mineral content fuel by coal liquefaction which yields as its primary product a mixture of liquids and solids, a part of which is suspended in the liquid. The suspended solids are effectively removed with a minimum loss of desired product by means of a precipitating solvent which serves three functions: (1) to effect agglomeration of the suspended fines, (2) to prevent redispersal of the fines in the washing operation, and (3) to recover desired product from the rejected solids.

6.3.4

COAL LIQUEFACTION

Inventors: Morgan C. Sze, George J. Snell

Assignee: The Lummus Company, Bloomfield, NJ

Filed: Nov. 7, 1972

Appl. No.: 304,319

Patent No.: 3,856,675

Date: Dec. 24, 1974

Abstract: Insoluble material is separated from a coal liquefaction product by use of a promoter liquid having a 5 volume percent distillation temperature of at least 250°F., most preferably at least 400°F and a 95 volume percent distillation temperature of at least 350°F and no greater than about 750°F. The liquid has a characterization factor of at least 9.75. By use of the promoter liquid, insoluble material can be effectively separated from the coal product by a gravity settling technique. A preferred gravity settling apparatus is also disclosed.

6.3.5

STUDIES ON THE SEPARATION OF COAL EXTRACT FROM MINERAL MATTER RESIDUE IN THE SOLVENT REFINING OF COAL

Briggs, D. E., Stirling, J. A.

Michigan University, Ann Arbor (USA), Dept. of Chemical Engineering

Dec 1974

National Science Foundation, Washington, D. C.

Abstract: Coal liquefaction processes were reviewed with respect to operating conditions that could influence or effect the removal of solids from coal extract. Catalytic coal liquefaction processes produced lower viscosity liquids than non-catalytic processes. The lower viscosity liquids are more amenable to solids separation. Several solids separation methods were reviewed and evaluated with respect to their potential to be effective in reducing the solids in liquified coal to an acceptable level. Vacuum distillation and pressure filtration appear to have the greatest potential. The choice depends upon the process, the coal, and the products produced. Hydroclones in conjunction with filtration also have merit. The solids residue from coal liquefaction contains inorganic solids, organic solids, and retained liquid which contains significant amounts of asphaltenes and larger molecular weight organic compounds. The small size of the solids and the tendency for asphaltenes to be adsorbed or precipitated when flowing through a porous medium contribute to filtration problems. The subject of asphaltenes was reviewed. Asphaltenes were extracted from solids residue samples from three liquefaction processes. The solids remaining after extraction were examined with a scanning electron microscope to identify and characterize the solids. An experimental filtration system was designed and the component parts ordered. It is proposed to use the equipment to study the effect of asphaltenes and asphaltene-extracted solids separately on the filtration rate. Subsequently coal would be liquefied and filtered to evaluate the results. The equipment is presently being assembled. Process modifications to improve solids separation were suggested. When filtration is used, it is possible that solids could be added to the process to control asphaltene precipitation and promote solids agglomeration. It is proposed to study and evaluate this concept.

6.3.6

SUPPORTING RESEARCH AND DEVELOPMENT ON SEPARATIONS TECHNOLOGY: PHASE I REPORT

Oak Ridge National Lab., Tenn.

Edwards, M. S.; Rodgers, B. R.; Salmon, R.

Mar 75 120p

Contract: W-7405-eng-26

Monitor: 18

NTIS ORNL-TM-4801

6.3.7

DEASHING OF COAL LIQUEFACTION PRODUCTS VIA PARTIAL DEASPHALTING -- HYDROGENATION AND HYDROEXTRACTION EFFLUENTS

Gorin, Everett; Kulik, C. J.; Lebowitz, H. E.

Conoco Coal Dev Co., Library, Pa

Am Chem Soc Div Fuel Chem Prepr v 20 n 1, 1975, for Meeting, Philadelphia, Pa.
April 6-11 1975 p 105-121

Abstract: A previous paper described the deashing of extraction effluents produced by hydrogen-donor extraction of bituminous and subbituminous coals. The present paper presents data on the extension of the same deashing technique to coal liquefaction products produced by direct hydrogenation of bituminous coal. Deashing experiments were conducted both with products produced by liquid-phase hydrogenation in the presence of an ebullated bed of hydrofining type catalyst (H-Coal Process) and with products produced by hydroextraction, i.e., without added catalyst (PAMCO Process). The hydroextraction products were produced in the CCDC bench-scale unit. Data are presented with respect to solvent balance, product yields and properties in hydroextraction as well as the deashing behavior of the hydroextraction effluents. Continuous unit data are presented in details for the hydroextraction work while the batch work is briefly summarized. Data are presented in detail for the hydroextraction work while the batch work is briefly summarized. Data are presented for deashing of H-coal bottoms in both batch and continuous units. 9 refs.

6.3.8

SUPPORTING RESEARCH AND DEVELOPMENT ON SEPARATIONS TECHNOLOGY. PHASE II REPORT: SCOUTING EXPERIMENTS

Oak Ridge National Lab., Tenn.

Rodgers, B. R., Katz, S.

Oct 75 145

Contract: W-7405-eng-26

Monitor: 18

Abstract: This report describes the second phase of a project sponsored by the Energy Research and Development Administration, Division of Fossil Energy, that has the objective of developing methods for accomplishing solid-liquid separations that are required for coal liquefaction processes. The first phase was a review and evaluation of available data and the formation of a plan for laboratory experiments. Phase II has consisted of characterization tests of COED and SRC process streams, and scouting tests for some alternative separation methods. A third phase will initiate bench-scale development of solvent fractionation-dilution, advanced filtrations, and continuation of the characterization tests.

NTIS ORNL-TM-4968

6.3.9

STUDIES ON THE SEPARATION OF COAL EXTRACT FROM SOLID RESIDUE IN LIQUEFIED COAL. PROGRESS REPORT

Dale E. Briggs and Peter A. S. Smith
University of Michigan, College of Engineering
DRDA Project 013722
November, 1975
National Science Foundation, Washington, D.C.
Grant No. NSF-AER 7515213

Abstract: The work accomplished during the first six months is reviewed in the areas of asphaltene extraction and characterization, filtration experiments, asphaltene adsorption and viscosity and surface tension measurements. Batch extraction procedures have been developed for extracting large quantities of asphaltenes from the residues of coal liquefaction processes. Asphaltenes have been extracted and characterized from a U.S. Bureau of Mines Synthoil centrifuge solids residue and extracted from a Hydrocarbon Research, Inc., H-Coal vacuum bottoms residue. Asphaltenes were separated into a number of molecular weight ranges by extraction and gel permeation chromatography. The molecular weight of a number of fractions were determined. The filtration equipment has been completed and is being checked out. The adsorption experiments have been planned and the equipment finalized. The viscosity of mixtures of low molecular weight (200-275) asphaltenes in tetralin were measured in the range of 30-90°C and 0-40 weight percent asphaltenes.

6.3.10

USE SOLVENT TO SEPARATE MICRON-SIZED PARTICLES FROM LIQUID STREAMS

Rodgers, B. R.
Oak Ridge Natl Lab, Tenn
Hydrocarbon Process v 55 n 5 May 1976 p 191-194

Abstract: This paper describes a new process for separation of small particulates from coal liquefaction process streams. This solvent agglomeration-fractionation process has been developed as an alternative to filtration. Following solvent addition, sulfur and ash contaminants are concentrated in a heavy phase by centrifugation or filtration, leaving a clarified product which meets most guidelines for sulfur and ash contamination. Effective filtration rates are also increased by solvent addition. The subject report is presented under headings -- background (bibliography-based review of research works); verification of agglomeration; separation of agglomerated mixtures (filtration, centrifugation). Experimental data are included. 12 refs.

6.3.11

RESEARCH ON CROSS-FLOW FILTRATION FOR SOLIDS REMOVAL FROM COAL SYNCRUDES. QUARTERLY TECHNICAL PROGRESS REPORT, FEBRUARY 17, 1967-May 31, 1976

Abcor, Inc., Wilmington, Mass. Walden Research Div.,
Energy Research and Development Administration
Tompkins, F. C., Jr.
Jun 76 11p
Contract: E(49-18)-2245
Monitor: 18

Abstract: The objective is to explore the utility of a cross-flow filtration process based upon the use of porous, tubular, sintered stainless steel filtration elements for the separation of particulate matter from crude SRC (solvent refined coal) slurry. Procedures and methods development will be investigated for the assessment of the following properties of SRC: Total suspended solids, suspended solids particle size distribution, viscosity as a function of temperature and total solids level, density, composition by fluorescence indicating analysis, and ASTM distillation curve. A batch recirculating bench scale system utilizing a single tubular filtration element will be designed for operation at up to 450°F and 250 psig. The experimental program to be carried out is designed to demonstrate process feasibility at the bench scale level and to establish optimum operating conditions. The major dependent variables to be measured are: Filtration rate; separation efficiency; and pressure drop of feed flowing through the filter elements. These dependent parameters will be measured as a function of the following independent variables: Filtration element; temperature; feed flow rate or velocity; filtration pressure driving force; and solids concentration level. For one filtration element, and the optimum operating conditions, a continuous run of 250 to 500 operating hours will be performed. An analysis of the data will provide estimates of continuous production capacity and maximum achievable solids concentrations. Based upon the experimental results, preliminary process economics will be generated for full-scale facilities (tentatively 5000, 25,000 and 100,000 BBL/day).

NTIS FE-2245-3

6.3.12

LABORATORY EVALUATION OF PRECOAT FILTRATION PARAMETERS FOR THE SOLVENT REFINED COAL PROCESS.

Katz, S., Rodgers, B. R.
Oak Ridge National Laboratory, Tenn.
Inds. Eng. Chem., Process Des. Dev. 15 July 1976
407-410

Abstract: The effect of temperature, pressure, filter cake thickness, and filter cake compressibility upon the filtration rate on unfiltered oil from the solvent refined coal liquefaction process was determined using a laboratory scale precoat filtration system.

6.3.13
COAL LIQUEFACTION

Inventors: Morgan C. Sze and George J. Snell
Assignee: The Lummus Company, Bloomfield, NJ
Filed: Sept. 6, 1974
Appl. No.: 503,673
Patent No.: 3,974,073
Date: Aug. 10, 1976

Abstract: Insoluble material is separated from a coal liquefaction product by gravity settling in at least two gravity settlers, with overflow from a previous settler being used as feed to the subsequent settler. A promoter liquid having characterization factor of at least 9.75, a 5 volume percent distillation of at least 250°F, and no greater than 750°F, is employed in each settler.

6.3.14
THE APPLICATION OF LUMMUS ANTISOLVENT DEASHING TECHNOLOGY TO A SOLVENT REFINED COAL SOLUTION

G. J. Snell and A. A. Simone
EPRI AF-234 (Research Project 524), Final Report, September 1976

Abstract: On July 7, 1975, C-E Lummus was authorized by the Electric Power Research Institute (EPRI) to investigate the application of Lummus' anti-solvent deashing technology to the solvent refined coal liquefaction process. Briefly, the work was divided into tasks, namely: a pilot plant test and an economic evaluation. For the first task, Lummus was to process a feedstock provided by EPRI's Wilsonville SRC pilot plant in its anti-solvent deashing pilot unit. A relative economic comparison between the Lummus deashing process and rotary pressure precoat filtration was the objective of the second task on economic evaluation. This latter comparison was made on a scale equivalent to a commercial size solvent refined coal liquefaction complex.

6.3.15
REFORMATION OF INORGANIC PARTICULATES SUSPENDED IN COAL-DERIVED LIQUIDS AND IMPROVED SEPARATION.

Katz, S.; Rodgers, B. R.
Oak Ridge National Lab., Tenn.
American Chemical Soc. Div. Fuel Chem Prepr, v 21 n 5 1976: Symp. on Coal Liq. 172nd Natl Meet, San Francisco, Calif. Aug 29-Sep 3 1976 p 8-18

Abstract: For coal liquefaction processes, the separation of fine inorganic particulates from the organic product matrix represents an important technical problem. This problem is difficult because the matrix is viscous and many of the particles are in the micron and submicron size range. Separation methods and devices tried with some success in separating the particles have been: hydroclones, centrifugation, magnetic separation, solvent extraction, solvent

fractionation, and filtration. These techniques suffer, however, in varying degrees from unsatisfactory operation, maintenance, throughput, and cost. This paper describes an experimental investigation which was undertaken to correct these shortcomings of particle separation by means of solvent addition. This paper consists of five parts. The first part describes the laboratory sedimentation test used in this study. In the second part the authors discuss the effects of solvent dilution on settling. Parts three and four present settling results achieved with heating and with the addition of chemical parameters. Finally the paper describes the possible mechanisms and the roles that each may play. Experimental data are enclosed and evaluated in terms of practical recommendations.

6.3.16

FILTRATION PROCESS AND EQUIPMENT STUDIES FOR COAL LIQUEFACTION PROCESSES. QUARTERLY REPORT, JUNE-AUGUST 1976

Smith, G. R. S., Himes, R. C.
Johns-Manville Sales Corp., Denver, Colo. (USA)
Contract E(49-18)-2007
27 Sep 1976

Abstract: A prime objective of the research project, doubling the filtration rate while maintaining satisfactory efficiency (clarification), is well within technical feasibility. The rate-limiting resistance to flow lies in the filter cake. Short immersion times (corresponding to high rotation rates) are a key to high filtration rates with unaltered feed stock. Body feed can be used to attain high filtration rates. Operating temperatures near the 600°F level are advantageous over those near the 500°F level, as regards filtration rate, and vastly better than those near the 400°F level. Increasing pressure differential is advantageous at least up to 35 to 40 psid. Additional let-down of 1FF is disadvantageous, at least at the 29 percent level, and higher ratios of SRC to process solvent may prove advantageous.

NTIS-FE-2007-2C

6.3.17

THE APPLICATION OF LUMMUS ANTISOLVENT DEASHING TECHNOLOGY TO A SOLVENT REFINED COAL SOLUTION. FINAL REPORT

Lummus Co., Bloomfield, N.J.
Electric Power Research Inst., Palo Alto, Calif.
Snell, G. J., Simone, A. A..
Sep 76 105p
Project: EPRI-524
Monitor: EPRI/AF-234

Abstract: This report investigates the application of the Lummus antisolvent de-ashing technology to the solvent-refined coal (SRC) liquefaction process. An economic comparison was made of the Lummus de-ashing process and rotary pressure precoat filtration.

NTIS PB-261 798/3ST

6.3.18

RESEARCH ON CROSS-FLOW FILTRATION FOR SOLIDS REMOVAL FROM COAL SYNCRUDES.
QUARTERLY TECHNICAL PROGRESS REPORT, JUNE 1, 1976--AUGUST 31, 1976

Tompkins, F. C., Jr.

Abcor, Inc., Wilmington, Mass. (USA). Walden Research Div.
Contract E(49-18)-2245 Sep 1976

Abstract: Major effort was directed toward the completion of equipment procurement and system construction activities. Supporting work was also carried out in the areas of: sample characterization, filtration element pore size distribution determination, and particle size distribution determination. A summary of these efforts is included.

NTIS-FE-2245-3

6.3.19

AGGLOMERATION AND SEPARATION OF MICRON-SIZED PARTICLES FROM COAL LIQUEFACTION STREAMS

Rodgers, B. R., Westmoreland, P. R.
Oak Ridge National Lab., Tenn (USA)
1976

Abstract: Optical microscopy was used to show agglomeration of solids produced by solvents such as toluene in coal conversion liquids. Settling and filtration rates were increased substantially after agglomeration. Results of laboratory experiments demonstrated that a 50 percent overflow of clarified specification product was obtained after settling for 1 hr., and that filtration rates were increased by a factor of 4. Process-derived solvent was also beneficial in increasing settling and filtration rates. However, the largest increases in filtration rates were realized by a combined settling-filtration operation. Ground coal was found to be an economical substitute for diatomaceous earth as a precoat material for filtration of coal conversion streams. Filtration rates were increased slightly by the ground coal precoat under standard operating conditions, but major rate increases were realized by maintaining ultra-thin filter cakes at the top of the coal precoat. Coal precoat, which may be collected with the solids in a commercial process, enhanced the value of the solids as a gasifier feed to produce hydrogen or methane. Ground coal can also be added to the liquid stream to serve as a "body feed" and produce increased filtration rates. The coal body feed would also provide an adjustable parameter for controlling the amount of hydrocarbon fed to the gasifier. Some recent advances using additives in the parts-per-million range to increase settling and filtration rates are discussed. Future research directions are outlined briefly.

NTIS CONF-760402-6

6.3.20

STUDIES ON THE SEPARATION OF COAL EXTRACT FROM SOLID RESIDUE IN LIQUEFIED COAL. FINAL REPORT

Dale E. Briggs, et al.
The University of Michigan
DRDA Project 013722
December 1976
NSF-AER 7515213

Abstract: Coal liquefaction residues from the Synthoil (Pittsburgh Seam) and H-Coal (Illinois No. 6) processes were solvent extracted into oils and resins, asphaltenes, preasphaltenes, and mineral solids for adsorption, filtration, surface tension, and viscosity measurements. Suspended solids in liquefied coal range from less than 0.05μ to greater than 1μ . Although small in total mass, the particles less than 0.2μ effect the flow properties of filter cakes by forming "micro" filter cakes which fill the interstices between the larger diameter particles forming the bulk "macro" filter cakes. Filter cake specific resistance varies as an inverse function of the number average particle size. THF insoluble solids from Synthoil product oil, H-Coal vacuum still bottoms and Synthoil centrifuge cake had number average particle sizes of 0.067, 0.971, and 0.147μ , respectively. When filtered from tetralin at 177°C , the specific resistances were 0.7×10^{12} , and 0.31×10^{12} m/kg, respectively. At temperatures below 200°C , the H-Coal filter cake compressibility was 0.36. The specific filtration resistance is temperature dependent above 200°C , being from 50 to 100% higher at 232°C than at 177°C . The increase is associated with softening of residual organic matter contained in the solids. The influence of drag forces on the softened particles reduces flow passages. Surface tension and reduced viscosity data for oils, resins, and asphaltenes in tetralin indicate intermolecular association and colloid micellization. At asphaltene and preasphaltene concentrations about 15%, micelle formation is significant. The micelles interact with porous media through which they flow to give an increase in cake resistance of 40-100%. This increase depends on the size of the micelles in relation to the size of the flow passages. Resins act to peptize the micelles, which limits their size.

6.3.21

DEASHING OF COAL LIQUEFACTION PRODUCTS VIA PARTIAL DEASPHALTING. HYDROGEN-DONOR EXTRACTION EFFLUENTS

Everett Gorin, Conrad J. Kulik, and Howard E. Lebowitz
Ind. Eng. Chem., Proc. Des. Devl. vol 16, no 1, 1977

Abstract: This article summarizes work carried out by Conoco Coal Development Co. on deashing of effluents produced by hydrogen-donor extraction of coal. The ash and undissolved coal residue are separated by simple gravity
(Cont'd)

settling. Settling rates are enhanced and product clarity is improved by a mechanism which involves partial precipitation of a relatively small quantity of dissolved asphalt from the extraction effluent solution. The fine particles are agglomerated by this precipitated asphalt. Several bituminous and subbituminous coal feedstocks were investigated. Investigations were conducted both in batch autoclaves and in a continuous bench-scale unit (30 lb/h feed rate). Good correlation was obtained between the results of the two units. Deashing by continuous settling was achieved after donor extraction of bituminous coals by simply cooling to 600°F. The ash content of the clarified extract was reduced to 0.2 wt%. For lower rank coals it is necessary to add a precipitating solvent. n-Decane was used for this purpose in the work reported here.

6.3.22

DEASHING OF COAL LIQUEFACTION PRODUCTS VIA PARTIAL DEASPHALTING. HYDROGENATION AND HYDROEXTRACTION EFFLUENTS

Everett Gorin, Conrad J. Kulik and Howard E. Lebowitz
Ind. Eng. Chem., Proc. Des. Dev. vol 16, no. 1, 1977

Abstract: The method of deashing via partial deasphalting described in the previous paper is extended to other coal liquefaction effluents. The effluents studied were those from two types of coal liquefaction processes. The first effluent was produced by the H-Coal Process, i.e., by hydrogenation of a coal-oil slurry in an ebullated bed of a hydrotreating catalyst. The second effluent was produced by solvent extraction in the absence of an added catalyst but under hydrogen pressure. The effluent in the latter case was produced simultaneous with the deashing runs in a single bench-scale unit containing the hydro and deashing units in tandem. Illinois No. 6 coal was used as feedstock for both liquefaction processes. In both instances the residue has a finer size consist than that produced via donor extraction. The addition of precipitating solvent is necessary to achieve adequate deashing in both instances via continuous settling. Clarified residuum products with ash contents as low as 0.13% ash were produced by this method. The effect of replacing the start-up anthracene oil solvent with natural coal-derived solvent on deashing is also reported. Yields, product quality, and solvent balance in hydroextraction are also reported. n-Decane was used exclusively as the precipitating solvent. The use of coal-derived saturated distillates as precipitants is now being investigated.

6.3.23

DESULFURIZATION OF SOLVENT REFINED COAL BY HIGH GRADIENT MAGNETIC SEPARATION

Research Project 365-1. Final Report, April 1977
Emmanuel Maxwell
Francis Bitter National Magnet Laboratory
Massachusetts Institute of Technology, Cambridge, Mass.
for Electric Power Research Institute

Abstract: Successful removal of inorganic sulfur from solvent refined coal by high gradient magnetic separation has been demonstrated. At the optimum temperature the inorganic sulfur removal was comparable with that achieved
(Cont'd)

by mechanical filtration, estimated at 99%; 20 to 40 percent of the ash was removed. The solids reduction is critically dependent on the temperature with maximum reduction at 430°F, where the magnetization of the filter cake solids exhibits a local maximum. Most of the tests were conducted at a magnetic field strength of 20 kOe and at flow velocities up to 3 cm/s. There appears to be no velocity dependence in this range. Performance is improved at higher field strengths (fields up to 80 kOe were investigated) and the temperature dependence is somewhat moderated. Preliminary tests on backwashing trapped solids from the matrix show 90 to 98 percent removal of the trapped solids and no significant build-up of residual solids on cyclic re-use of the matrix.

6.3.24

THE APPLICATION OF LUMMUS ANTISOLVENT DEASHING TECHNOLOGY TO A WELL CONVERTED SOLVENT REFINED COAL SOLUTION

EPRI AF-473, (Research Project 524-2) Final Report June 1977

George Snell

The Lummus Company

for Electric Power Research Institute

Abstract: This report supplements the previous CE-Lummus report on the "Application of Lummus Antisolvent Deashing Technology to a Solvent Refined Coal Solution: (AF-234), dated June 30, 1976. That report presented experimental data on the application of Lummus' antisolvent deashing technology and an economic comparison between the Lummus deashing process and deashing via current state-of-the-art rotary precoat filtration for a commercial size Solvent Refined Coal complex, based on a poorly converted coal solution deashing feedstock. The purpose of this report is to present similar experimental data and an economic comparison for a well converted (95% MAF coal), SRC derived deashing feedstock. The feedstock was prepared at the Wilsonville SRC pilot plant from an Illinois No. 6 (Monterey Mine) source coal. A 99+% ash removal was observed when an antisolvent/feedstock wt. ratio and underflow withdrawal of 0.55 and 25 wt.%, based on total settler feed, respectively, was employed. An economic comparison of Lummus Antisolvent Deashing with filtration indicated that, for the higher conversion case, deashing was economically superior to filtration to a greater extent than in the lower conversion case.

6.4 CHAR UTILIZATION

Several articles on utilization of residue or char from coal liquefaction processes are included here. Early papers report on the recovery of mineral values from the char. Later papers focus on the utilization of char, which contains considerable carbon values, for gasification and ultimately for hydrogen manufacture. Most of the papers cover laboratory studies by Pittsburgh and Midway Coal Mining Company, Washington State University, I.G.T., EPRI and others. There is one paper from Texaco describing large scale gasification of SRC residue.

6.4.1

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL. VOLUME IV. PRODUCT STUDIES. PART 3. PRODUCTS FROM COAL MINERALS

Pittsburgh and Midway Coal Mining Co., Kansas City. Mo. Office of Coal Research, Washington, D.C. Washington State University, Pullman. Coll. of Engineering Research Div.

Interim Report no. 11

Nov 74 51p

Contract: DI-14-01-0001-496

Monitor: OCR-53-INT-11

See also PB-237 765. Prepared in cooperation with Washington State Univ., Pullman Coll. of Engineering Research Div.

Abstract: Feasibility of producing products from mineral residue of the Solvent Refined Coal (SRC) Process is discussed. Experimental studies included the processing of sulfur, iron and the production of mineral wool. A review of the experimental procedure and results is given.

NTIS PB-237 764/6ST

6.4.2

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL. VOLUME IV. PRODUCT STUDIES. PART 4. SULFUR REMOVAL FROM COAL MINERALS

Pittsburgh and Midway Coal Midway Coal Mining Co., Kansas City Mo. Office of Coal Research, Washington, D. C. Washington State University, Pullman Coll. of Engineering Research Div.

Interim Report No. 12

Nov 74 40p

Contract: DI-14-01-0001-496

Monitor: OCR-53-INT-12

See also PB-237 766. Prepared in cooperation with Washington State University Pullman. Coll. of Engineering Research Div.

Abstract: Sulfur removal from residual solids of the Solvent Refined Coal (SRC) Process is investigated. The residue, called coal minerals, contains various amounts of ferrous oxide, silica, carbon, and alumina. The preferential oxidation technique for sulfur removal was tested on the coal mineral for the oxidation of ferrous sulfide. The process is reviewed and results are reported.

NTIS PB-237 765/3ST

6.4.3

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL. VOLUME IV. PRODUCT STUDIES. PART 5. DEVELOPMENT AND RATE STUDIES IN PROCESSING OF COAL MINERALS.

Pittsburgh and Midway Coal Mining Co., Kansas City, Mo. Office of Coal Research, Washington, D. C. Washington State University, Pullman Coll. of Engineering Research Division
Interim Report no. 13

Nov 74 139p

Contract: DI-14-01-0001-496

Monitor: OCR-53-INT-13

See also PB -237 763. Prepared in cooperation with Washington State University, Pullman Coll. of Engineering Research Division

Abstract: Processing of coal minerals from the Solvent Refined Coal (SRC) Process is discussed. The report reviews the chemical reactions and kinetics of carbon gasification for the production of fuel as synthesis gas and subsequent recovery of elemental iron and sulfur.

NTIS PB-237 766/1st

6.4.4

LOW-TEMPERATURE CARBONIZATION OF SOLID RESIDUES FROM BITUMINOUS COAL EXTRACTION

Rusin, E., Pawlak, L., Potyka, W.

Extraction with anthracene oil at 330 to 450°C production of semicoke, oil, and gas

Koks, Smola, Gaz 20/3/1975
69-72

6.4.5

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL. VOLUME IV. PRODUCT STUDIES. PART 2. AN ANNOTATED BIBLIOGRAPHY ON MINERAL FIBER PRODUCTION FROM COAL MINERALS

Washington State University, Pullman Research Division (6794000)

66p

Contract: 14-01-0001-496

Monitor: 18

Abstract: The literature search performed in support of research on mineral fiber production from the residual solids of the Solvent Refined Coal Process is summarized.

NTIS OCR-53-INT-10

6.4.6

SURVEY OF HYDROGEN PRODUCTION AND UTILIZATION METHODS. VOLUME 1:
EXECUTIVE SUMMARY

Institute of Gas Technology, Chicago, Ill.

Final Report

Gregory, D. P., Pangborn, J. B., Gillis, J. C.

Aug 75 41p

Report No: NASA-CR-144127

Contract: NAS8-30757

Monitor: 18

Abstract: The use of hydrogen as a synthetic fuel is considered. Processes for the production of hydrogen are described along with the present and future industrial uses of hydrogen as a fuel and as a chemical feedstock. Novel and unconventional hydrogen-production techniques are evaluated, with emphasis placed on thermochemical and electrolytical processes. Potential uses for hydrogen as a fuel in industrial and residential applications are identified and reviewed in the context of anticipated U.S. energy supplies and demands. A detailed plan for the period from 1975 to 1980 prepared for research on and development of hydrogen as an energy carrier is included.

NTIS N76-15590/2ST

6.4.7

SURVEY OF HYDROGEN PRODUCTION AND UTILIZATION METHODS. VOLUME 2:
DISCUSSION

Institute of Gas Technology, Chicago, Ill.

Final Report

Gillis, J. C., Gregory, D. P., Pangborn, J. B.

Aug 75 477p

Report No: NASA-CR-144128

Contract: NAS8-30757

Monitor: 18

NTIS N76-15591/OST

6.4.8

CHARACTERIZATION OF MINERAL MATTER IN COALS AND COAL LIQUEFACTION RESIDUES

Electric Power Research Institute

Research Project 366-1

Annual Report, December 1975

Walker, P.L., Jr., Spackman, W., Given, P.H., White, E.W., Davis, A.,
Jenkins, R.G.

Coal Research Section, College of Earth and Mineral Sciences, Pennsylvania
State University, University Park, Pa. 16802

Abstract: This is the first annual report describing results of a research program on the "Characterization of Mineral Matter in Coals and Coal Liquefaction Residues". The program began January 1, 1975 and is scheduled to run through December 31, 1977.

Characterization techniques which we have employed this first year include:

- i) Reflectance of organic and inorganic fractions in incident light
- ii) Light microscopy
- iii) Computer evaluation of scanning electron microscope images
- iv) Infrared spectroscopy
- v) X-ray diffraction
- vi) Sedimentation
- vii) Surface areas from gas adsorption
- viii) Helium densities
- ix) Magnetic measurements
- x) Transmission electron microscopy

It was shown in this report that a number of these techniques complement each other in making it possible to characterize chemically and physically the mineral matter in American coals and the residues resulting from their hydrogenative liquefaction.

6.4.9

COAL CHAR GASIFICATION USING ALKALI METAL CATALYSTS

California University, Berkeley. Lawrence Berkeley Lab. Energy Research and Development Administration. (1112800)

Veraa, M. J., Bell, A. T.

Apr 76 105p

Contract: W-7405-ENG-48

Monitor: 18

Thesis.

Abstract: In order to simplify the experimental procedure and the interpretation of results, coal char rather than coal was used to study steam gasification of a Wyoming sub-bituminous coal with alkali metal salts as catalysts. Coal/catalyst contacting was accomplished by aqueous impregnation of the coal with catalyst. Gasification rates and gas production rates were measured as a function of catalyst type, catalyst loading, and reactor temperature. Steam partial pressure was maintained constant at one half of an atmosphere. Temperature was varied from 600 to 900 exp 0 C. Initial catalyst screening studies indicated that K_2CO_3 and KOH gave identical results and that both were superior to alkali chlorides in enhancing gasification rates. K_2CO_3 was then used exclusively in all subsequent studies. The following major conclusions can be drawn:

(cont'd)

Enhancement in the gasification rate results from increased catalyst loading and decreased thermal aging: activation energies decrease with increasing catalyst loading and have values of 39.1, 44.8, and 49.1 Kcal/mole for 10, 5, and 0 percent loadings of potassium, respectively: increasing temperature causes carbon monoxide to be formed in preference to carbon dioxide and hydrogen, but diminishes the rate of methane production.

NTIS LBL-4498

6.4.10

HYDROGEN PRODUCTION FROM COAL LIQUEFACTION RESIDUES

Texaco, Inc., South El Monte, Calif. Montebello Research Lab.

Electric Power Research Inst., Palo Alto, Calif.

Final Report

Robin, Allen M.

Dec 76 72p

Project: EPRI-714-1

Monitor: EPRI/AF 233

Abstract: High ash H-coal residues from the liquefaction of Illinois No. 6 and Wyodak coals were gasified in a Texaco Synthesis Gas Generator at Texaco's Montebello Research Laboratory. The synthesis gas produced consisted of over 92 volume percent carbon monoxide (CO) and hydrogen (H₂) on a dry basis. Approximately 40 tons of each residue was gasified at 24 atmospheres pressure at residue feed rates up to 1/2 ton per hour. No major operating problems were experienced. Cold gas efficiencies averaged between 83 and 84 percent. Steam and oxygen requirements were comparable to those of heavy oil gasification. Enough data have been obtained to verify existing computer correlations and to establish information needed to provide a commercial plant design for these two, and other similar, coal liquefaction residues.

NTIS PB-261 734/8ST

6.5 SRC PRODUCT CHARACTERIZATION

Publications listed in this section describe the characteristics of SRC products. Reports on laboratory and pilot plant tests to evaluate SRC as a fuel including storage, handling and combustion characteristics are also included. Papers related to neutron activation analysis and elucidation of coal structure are listed. Molecular profile analysis and gel permeation chromatographic analysis of SRC are described in some papers.

6.5.1

NEUTRON ACTIVATION ANALYSIS OF SOLVENT REFINED COAL

McKown, D. M., Kay, M. A.

University of Missouri, Columbia

American Chemical Society, Div. Environ. Chem., Prepr. 15/1/1975

194-195

Abstract: An examination is made of some of the sample handling and procedure evaluation experiences related to the neutron activation analysis of coal and solvent refined coal products. In addition elemental concentrations obtained from the analysis of some of these materials are reported. 1 ref.

6.5.2

INVESTIGATING THE STORAGE, HANDLING AND COMBUSTION CHARACTERISTICS OF SOLVENT REFINED COAL

Babcock and Wilcox Co., Barberton, Ohio. Fossil Dept. Electric Power Research Inst., Palo Alto, Calif.

Final report

Barrick, S. M., Jones, F. L., Vecchi, S. J.

Oct 75 222p

Monitor: EPRI-1235-1-FR

Abstract: This report describes E-21 pulverizer (ball-and-race) testing and direct firing of a Stirling boiler. Objectives were to demonstrate (1) the suitability of commercial ball-and-race mills to pulverize solvent refined coal (SRC), and (2) the possibility for direct firing of pulverized SRC from a ball-and-race mill. The program was divided into four-experimental tasks: mill preparation, mill testing, mill modification, and a direct firing demonstration. The results demonstrated the suitability of a commercial ball-and-race mill for pulverizing SRC after some modifications in speed and ball pressure and the feasibility of direct firing of pulverized SRC from a ball-and-race mill.

NTIS PB-248 539/9ST

6.5.3

LABORATORY ANALYSIS OF SOLVENT REFINED COAL

C-E Power Systems, Windsor, Conn.

Electric Power Research Inst., Palo Alto, Calif.

Technical Report no. 1

Borto, R. W.

Jun 76 56p

Project: EPRI-1235

Monitor: EPRI-1235-2a

Abstract: With respect to air pollution control in electric power generation, two basic routes are being pursued; one is to clean up the flue gas before admitting it to the atmosphere and the other is to clean up the fuel before
(cont'd)

it is burned in the utility boiler. Southern Services Company has been actively pursuing a Solvent Refined Coal (SRC) process and has completed construction of a pilot plant at Wilsonville, Alabama in late 1973. The Southern Services process solubilizes about 95 percent of the moisture-ash-free coal in a dissolver operated at 1800 psig and 825F with a residence time on the order of 30 minutes. Combustion Engineering, under EPRI funding, has agreed to conduct a bench-scale analysis of the solvent refined coal (and base coal) produced by Southern Services' Wilsonville pilot plant. The objective of this study is to determine, within the limits of bench-scale analysis, the technical feasibility of using Southern Services' SRC as a utility power plant fuel.

NTIS PB-255 550/6ST

6.5.4

SOLVENT REFINED COAL EVALUATION: PULVERIZATION, STORAGE AND COMBUSTION

C-E Power Systems, Windsor, Conn.

Electric Power Research Inst., Palo Alto, Calif.

Technical Report no. 2

Borio, R. W., Fink, Z. J., Goetz, G. J., Haas, J. C.

Jun 76 124p

Project: EPRI-1235

Monitor: EPRI-1235-2b

Abstract: A laboratory analysis revealed several important characteristics of SRC that could affect its pulverization. It was determined that SRC melts at 310F. In normal mill operation, preheated air as hot as 700F is frequently used; therefore, a problem due to melting of SRC in the mill could exist if the preheated air temperature were over 310F. The Hardgrove grindability index for SRC is 145, indicating that the power required to pulverize SRC should be significantly less than that required for base coal. During preliminary testing in the Hardgrove grindability apparatus, SRC which had moisture contents of 5% or less was compacted rather than pulverized. It appeared from these tests that moisture was an important property with respect to pulverization. The pulverization of SRC was investigated using a C-E Deep Bowl Mill, No. 271.

NTIS PB-255 729/6ST

6.5.5

COMBUSTION OF PULVERIZED, SOLVENT-REFINED COAL

McCann, C. R.; Demeter, J. J.; Bienstock, D.

Pittsburgh Energy Res Cent, Pa

Combust Inst. Cent States Sect., Spring Meet, Columbus, Ohio, Apr 5-6 1976

Sponsored by Combust Inst., Pittsburgh, Pa, 1976 11p

Abstract: The handling, pulverizing, combustion, and fouling characteristics of solvent-refined coal (SRC) were studied in a multi-burner, water-wall furnace designed to burn pulverized, bituminous coal at a rate of 500 lb/hr. The
(Cont'd)

SRC, which was produced from a high-sulfur Illinois coal, contained 0.8% sulfur and 0.3% ash, had a heating value of 15400 Btu/lb and a fluid temperature less than 300°F. When operating at secondary air temperatures of 500-600°F it was necessary to water-cool the primary air-coal passages and burner nozzle to prevent melting and subsequent fouling. In addition, secondary air swirl adjustments were made to optimize recirculation and flame shape to overcome burner fouling. Although flame temperatures obtained with SRC were several hundred degrees (°F) higher than those obtained with bituminous coal, NO_x emissions were considerably lower than those obtained with coal fired through the more conventional burners originally used in the combustion system. Sulfur oxide emissions of 0.8 to 1.0 lb SO₂ per 10⁶ Btu would meet emission regulations in most air regions in the United States. Carbon conversion values were similar to those obtained when firing bituminous coal. 2 refs.

6.5.6

INTERFERENCES REGARDING THE NATURE OF SOLVENT-REFINED COAL (SRC)

Wooton, D. L., Dorn, H. C., Taylor, L. T., Coleman, W. M.
Virginia Polytechnic Inst. and State University, Blacksburg
Fuel 55 3 Jul 1976 224-226

Abstract: Solvent-Refined Coal product has been subjected to numerous analytical techniques in an effort to ascertain its chemical nature. Electron spin, resonance, nuclear magnetic resonance, and mass spectroscopy along with elemental and molecular weight analyses have been employed. High-performance liquid chromatography via gel permeation separates tetrahydro furan-soluble SRC into several size fractions. Nuclear magnetic resonance data strongly suggest that hexamethylphosphoramide-soluble SRC is approximately 95 percent aromatic in character.

6.5.7

SOLVENT REFINED LIGNITE AND SOLVENT REFINED COAL STRUCTURAL FEATURES COMPUTERIZED METHODOLOGY DEVELOPMENT

Woolsey, N., Baltisberger, R., Klabunde, K., Stenberg, V., Kaba, R.
University of North Dakota, Grand Forks

7 Refs.

American Chemical Society Div. Fuel Chem. Prepr., 21/7/1976
33-51

American Chemical Society Meeting
San Francisco, Calif., United States of America (USA)

Abstract: Solvent Refined Lignite (SRL) and bituminous coal (SRC) are by definition very nonvolatile substances, but are quite soluble in certain organic solvents. Thus, MS-computer techniques are not very applicable for deriving structural information. However, many other powerful spectroscopic techniques are applicable. An attempt is being made to computerize an approach for gaining a great deal of information rapidly about average molecules in SRL and SRC, based on experimental data obtained from NMR, UV, average molecular weight, total analyses, acidities, and basicities. In addition, fluorescence-phosphorescence spectra and more unusual NMR techniques may be used in the future. For comparisons SRL or SRC is separated into acids, bases, and neutrals by column chromatography and each fraction subjected to analyses. Also, liquids derived from catalytic hydrotreating or SRL or SRC are subjected to MS-computer analysis as well as these solution spectroscopic techniques, and comparisons made. Mixtures of pure model compounds are also subjected to the analyses for standardization purposes. "Average Molecule" comparisons of SRL and SRC from batch and continuous processes have been made and information has been obtained on the acid-base functionalities, size and type of aromatic groups and connecting links. Also, the computerized approach outlined including "Dominance Tests" for measuring the worth of certain data.

6.5.8

INVESTIGATING STORAGE, HANDLING, AND COMBUSTION CHARACTERISTICS OF
SOLVENT REFINED COAL. TASK C EXTENSION, BALL-AND-RACE PULVERIZATION
AND DIRECT FIRING

Babcock and Wilcox Co., Barberton, Ohio. Fossil Dept. Babcock and
Wilcox Co., Alliance, Ohio. Alliance Research Center. Electric
Power Research Inst., Palo Alto, Calif.

Final Report

Downs, W., Jones, F. L., Sage, W. L., Wagoner, C. L.

Jul 76 126p

Project: EPRI-1235-3

Monitor: EPRI-1235-4

Prepared in cooperation with Babcock and Wilcox Co., Alliance, Ohio
Alliance Research Center.

Abstract: The solvent refining of coal is one of several approaches currently being evaluated by government and private sources to produce a clean fuel from coal. The primary objective of this contract is to characterize certain properties of solvent refined coal including storage, handling, and combustion. Knowing these properties will aid boiler manufacturers to design new units for burning solvent refined coal and to help determine retrofit requirements for existing units. The test program reported here was designed to explore the suitability (or unsuitability) of conventional pulverizing and combustion equipment to pulverize and burn solvent refined coal. This report describes modifications made to the equipment and presents the results obtained therein. Specialized instrumentation was added to the pulverizer during these tests to monitor vibration, torque, speed, etc. These tests are reported in detail. Since several terms used in this report are not in general usage, a glossary of terms and expressions relating to ball-and-race pulverizers and pulverized coal combustion are included.

NTIS PB-257 551/2ST

6.5.9

INVESTIGATING STORAGE, HANDLING, AND COMBUSTION CHARACTERISTICS OF
SOLVENT REFINED COAL

Babcock and Wilcox Co., Alliance Ohio, Alliance Research Center. Babcock
and Wilson Co., Barberton, Ohio. Fossil Dept. Electric Power Research
Inst., Palo Alto, Calif.

Final Report

Barrick, S. M., Vecchi, S. J., Wagoner, C. L.

Aug 76 120p

Project: EPRI-1235-3

Monitor: EPRI-1235-3-FR

Prepared in cooperation with Babcock and Wilson Co., Barberton, Ohio.
Fossil Dept.

Abstract: The 1235 series of reports documents the results of the investigation of the storage, handling, and combustion characteristics of solvent refined coal (SRC). Such information would permit boiler manufacturers to

(cont'd)

design new units for burning SRC and to determine retrofit requirements (if any) for existing units burning coal. The SRC reports summarize activity for a wide range of tasks. Initial work included bench-scale analyses of SRC, such as fuel analysis, pulverizing and transport. The culmination of the effort was a 2-ton/hour ball-and-race pulverizing and direct-firing test to simulate as closely as possible operating conditions in a utility plant using conventional equipment.

NTIS PB-257 557/9ST

6.5.10

PRELIMINARY EXAMINATION OF COAL LIQUEFACTION PRODUCTS

Schwager, I.; Yen, T. F.

Univ. of South Calif, Los Angeles

v 21 n 5 1976: Symp on Coal Liq, 172nd Natl Meet, San Francisco, Calif.

Aug 29-Sep 3 1976 v 21 n 5 1976:

Abstract: The three direct general processes for converting coals to liquid fuels are: catalyzed hydrogenation, staged pyrolysis, and solvent refining. Each of these processes result in the production of a coal liquid which contains a variety of desirable and undesirable components. The desirable coal liquids are the oils-saturated and aromatic hydrocarbons plus nonpolar nonhydrocarbons, and the resins-polar nonhydrocarbons. In the reported work, coal liquids from representative liquefaction processes have been separated by solvent fractionation, and the fractions are being examined by various analytical and physical techniques. Particular attention is being directed toward asphaltene separation, purification and characterization. Each coal liquid has been separated into five different fractions. Total recoveries ranging from 93 to 97% by weight have been obtained. These solvent fractions are respectively: oil, resin, asphaltene, carbene and carboid. 12 refs.

6.5.11

SOLVENT REFINED LIGNITE AND SOLVENT REFINED COAL STRUCTURAL FEATURES. COMPUTERIZED METHODOLOGY DEVELOPMENT

Woolsey, N.; Baltisberger, R.; Klabunde, K.; Stenberg, V.; Kaba, R.

Univ. of ND, Grand Forks

Am Chem Soc Div Fuel Chem Prepr v 21 n 7 1976, Pap presented at Am Chem Soc Natl Meet, 172nd, San Francisco, Calif, Aug 29-Sep 3 1976 p 33-51

Abstract: Treatment of coals at high temperature and pressure with hydrogen or water and carbon monoxide or both in certain vehicle solvents results in the partial "depolymerization" and reduction of coal. The resulting products, solvent refined coals (SRC), which are freed of solvent and ash by coupled filtration or extraction processes, have lower molecular weights, higher
(Cont'd)

hydrogen and Btu contents, less sulfur and in general greater solubility in solvents. These properties make SRC's desirable boiler fuels as well as reactants for further hydrogenation to premium liquid fuels and chemical feedstocks. In this paper results are presented of investigation of solvent refined low rank coal; lignite or SRL; it has properties similar to SRC. SRC's and SRL's cannot readily be structurally investigated by the powerful gas chromatography - mass spectral methods because of their non-volatile nature. Therefore, the authors have sought alternative general methods for characterizing soluble but non-volatile samples such as SRC and SRL. This communication describes experimental techniques, results, and a computerized modeling method for the chemical characterization of non-volatile coal derived materials. Extensive experimental data are tabulated and evaluated.

6.5.12

A STUDY OF TRACE ELEMENT DISTRIBUTION IN A COAL CONVERSION PROCESS USING NEUTRON ACTIVATION ANALYSIS

Filby, R. H., Shah, K. R., Sautter, C. A.

1976 International Conference: Modern Trends in Activation Analysis

Munich, Federal Republic of Germany

13 to 17 Sep 1976

Abstract: Neutron activation analysis is an important tool in determining the nature and behavior of trace elements during coal liquefaction. The multi-element nature of the method and the ability to analyze very different matrixes, coupled with the low concentrations in many of the fractions, makes INAA the method of choice for determining trace element material balances in coal conversion. This study has shown that the SRC processes results in a fuel with much lower trace element contents than coal and that several elements are bound both organically and inorganically in the product SRC.

6.5.13

SEPARATION AND STRUCTURE ELUCIDATION OF COAL MOLECULE FRAGMENTS. PROGRESS REPORT, FEBRUARY 1, 1976 -- JANUARY 31, 1977.

Todd, L. J., Schultz, R., Novotny, N. V., Maskarinec, M. P.

Indiana University, Bloomington, (USA)

9 Refs.

Contract EY-76-S-02-2856

Oct 1976

Abstract: To date there have been only a few reports concerning the types and quantities of products present in solvent-refined coal. In these studies a compound-by-compound separation and identification was not possible. In certain biochemical applications, separation problems of a similar nature have been overcome by use of a combined gas chromatograph--mass spectrometer with a high resolution glass capillary column. The initial experiments designed to assess the feasibility of separating and identifying some constituents of solvent-refined coal (SRC) using this GC--MS method are

(cont'd)

outlined. The solid product and not the recycle oil are being examined. Polymerization, Oxidation, and other new product-generating processes occur during these separation procedures. Initially, simple separation procedures have been used that fairly rapidly permitted testing. The glass capillary-- gas chromatography--mass spectrometer method. In future work, it is planned to work out the best separation scheme for these materials.

NTIS C00-2856-1

6.5.14

DEUTERIUM TRACER METHOD FOR INVESTIGATING THE CHEMISTRY OF COAL LIQUEFACTION

Quarterly Technical Progress Report, June-September 1976

Skowronski, R. P., Ratto, J. J., Heredy, L. A.

Atomics International Division, Canoga Park, Calif.

October 1976

Work Performed Under Contract EX-76-C-01-2328

Abstract: The objective of this research is to achieve a better understanding of the mechanism of coal hydrogenation. A deuterium tracer method is being developed to achieve that objective.

Three exploratory hydrogenation tests have been completed and the products solvent-fractionated. The solubility data appear to be consistent with a simplified sequential reaction mechanism. Also, the first test in the planned series of protium/deuterium test pairs has been completed. Solvent-fractionation of the products is in progress.

The soluble products from all three exploratory hydrogenation experiments have been analyzed by proton nuclear magnetic resonance spectroscopy. Evaluation of the products from the first two tests is complete; evaluation of the products from the third is in progress. The data give the relative number of protons in different structural positions. Soluble products from the deuteration experiment are being analyzed by proton-NMR and will also be analyzed directly with a deuterium probe. This will give a direct check of the data obtained by difference from the proton-NMR spectra. Also, the absolute weight fraction of the deuterium in these products will be determined by combustion analysis. The water formed in these analyses will be trapped out and analyzed by mass spectrometry for $^1\text{H}_2\text{O}$ and $^2\text{H}_2\text{O}$ content.

The preliminary selection of model compounds for future hydrogenation/deuteration tests has been completed. These model compounds will be used to calibrate the NMR spectrometric method for analysis of Phase I data. This work will also establish a firm foundation for and facilitate transition to Phase II of the research.

ERDA-FE-2328-4

6.5.15

CHARACTERIZATION OF COAL LIQUIDS. INTERMEDIATE REPORT. Hydrocracking
Upgraded Solvent Refined Coal (SRC)

deRosset, A. J., Tan, G.

UOP, Incorporated, Des Plaines, Illinois

November 1976

Work Performed Under Contract No. EX-76-C-01-2010

Abstract: In the hydrotreating processability study of Solvent Refined Coal (SRC) in addition to studying the effects of various variables, a preparative hydrotreating run was made to produce 4.5-gallons of upgraded SRC for use as feedstock in a hydrocracking study. This charge stock serves as the last of eight ERDA coal liquids to be characterized as to processability by conventional petroleum refining technology.

The upgraded SRC, containing 9.8% C₇-insolubles and 70.1% 650°F+ bottoms, was processed over a commercial hydrocracking catalyst at four sets of conditions, including a catalyst activity check at startup conditions at the conclusion of the run. At base space velocity, 10°C above base temperature, and 200 psig above base pressure, conversion, defined as percentage disappearance of 650°F+ bottoms, was only 11.8%. This low yield of 650°F+ distillate is attributed to the presence of high molecular weight asphaltic materials.

ERDA-FE-2010-08

6.5.16

CHARACTERIZATION OF COAL LIQUIDS DERIVED FROM THE H-COAL PROCESS

S. A. Holmes, P. W. Woodward, G. P. Sturm, Jr., J. W. Vogh,
and J. E. Dooley

Bartlesville Energy Research Center, Bartlesville, Okla.

Nov. 1976 ERDA Tech. Info. Center BERC/RI-76/10

Distribution Category UC-926

Abstract: Compositional data of coal liquid products derived from the H-Coal process were obtained. Two overhead products (one from the fuel oil mode of operation and the other from the syncrude mode of operation) were prepared by Hydrocarbon Research, Inc. from Illinois No. 6 coal. The compositional data of these products are tabulated, and characteristics of the materials are discussed. Separation and characterization methods, with slight modification, as developed by the Bureau of Mines-API Research Project 60 for characterizing heavy ends of petroleum were successfully used in analyzing coal liquid distillates within the boiling range 200° to 540° C. Distillates boiling below 200° C were separated and analyzed using chromatographic and spectral techniques.

6.5.17

FULL SCALE UTILITY BOILER TEST WITH SOLVENT REFINED COAL (SRC), TECHNICAL
PROGRESS REPORT, JULY -- NOVEMBER 1976

McRanie, R. D.

Southern Co. Services, Inc., Birmingham, Alabama (USA)

Contract EX-76-C-01-2222

30 Nov 1976

Abstract: SRC burn test activities during the period July through November 1976 are presented. During this period there have been four SRC unloadings at Plant Mitchell, with one additional unloading expected. Dust generated during unloading and handling of SRC is still a major problem, however, dust control evaluations are underway and recommendations will be forthcoming. The burner development program sponsored by Electric Power Research Institute (EPRI) at Babcock and Wilcox (B & W) was completed with the development of a burner acceptable for use at Plant Mitchell during the SRC test burn. A subcontract between B & W and Southern Company Services (SCS) has been approved by ERDA, and additional subcontract activities are in progress. Installation of test instrumentation is proceeding at Plant Mitchell, and evaluation to determine the adequacy of other existing instrumentation is underway. A new schedule for the test burn program has been adopted, however, retrofit and test plans remain unchanged.

NTIS FE-2222-1

6.5.18

MOLECULAR PROFILE ANALYSIS OF COAL PRODUCTS

EPRI AF-390

Final Report

Feb 1977

Michael Anbar, principal investigator

Stanford Research Institute

Abstract: This report describes a new approach to the characterization of coal liquefaction products by a detailed molecular weight profile analysis. A methodology and instrumentation have been developed utilizing field ionization mass spectrometry to produce molecular weight profiles of coal liquefaction products in the mass range 100 to 1000 amu, including coal oils and asphaltenes.

The computerized technique allows the distinction between primary constituents and secondary pyrolytic products. Preliminary experiments with field desorption to analyze asphaltenes and preasphaltenes yielded encouraging results. This report also discusses the possibility of determination of the chemical structure of individual constituents in a complex multicomponent mixture by collision-induced dissociation.

6.5.19

ANALYTICAL CHARACTERIZATION OF SOLVENT REFINED COAL COMPARISON WITH PETROLEUM RESIDUA.

Callen, R. B.; Simpson, C. A.; Bendoraitis, J. G.

Mobil Res & Dev Corp, Paulsboro, NJ

Am Chem Soc Div Pet Chem Prepr v 22 n 2 Mar 1977; Anal Chem of Tar Sands and Oil Shale, New Orleans, La. Mar 20-25 1977 p 656-664

Abstract: In this study, gradient elution chromatography (GEC) has been employed to separate solvent refined coals, produced from three different coal sources, into well defined fractions. These fractions have been examined by C-13 and H-NMR techniques to gain some insight into the aromatic nature of the various fractions, and by infrared spectrometry to determine the nature of functional groups present therein. Particular attention has been paid to the distribution of heteroatoms N, O and S within the chromatographic cuts. Data from these SRC's are compared and contrasted to comparable data from a petroleum vacuum resid. 16 refs.

6.5.20

MINOR AND TRACE METAL ANALYSIS OF A SOLVENT-REFINED COAL BY FLAMELESS ATOMIC ABSORPTION.

Coleman, William M.; Szabo, Peggy; Wooton, David L.; Dorn Harry C;

Taylor, Larry T.

Virginia Polytech Inst & State Univ, Blackburg

Fuel v 56 n 2 April 1977, p 195-198

Abstract: Solvent-refined coals (SRC) have been analyzed for eleven metallic elements via flameless atomic absorption spectroscopy. Prior to analysis each sample was wet ashed with equal quantities of concentrated H₂SO₄ and 30% H₂O₂. Matrix effects were compensated for by the method of standard additions and deuterium-arc background correction. Mg, Al, K and Fe were found in greatest concentration in all samples. The concentration of Pb and Cd was measurable only in the THF-insoluble SRC. 12 refs.

6.5.21

PREPARATIVE GEL PERMEATION CHROMATOGRAPHIC SEPARATION OF SOLVENT REFINED COAL

Coleman, W. M., Wooton, D. L., Dorn, H. C., Taylor, L. T.
Virginia Polytechnic Inst. and State University Blacksburg
Tetrahydrofuran and Chloroform evaluation of 3 column packings
Anal. Chem. 49 4 Apr 1977
533-537

Abstract: A preparative quantitative separation of THF- and CHCl_3 soluble solvent refined coal (Pittsburgh No. 8) has been demonstrated employing gel permeation chromatographic techniques utilizing three column packings: a styrene--divinyl benzene packing (bio-beads S-X4), A cross-linked poly (n-acryloylmorpholine) polymer (enzacryl gel K-1), and a modified alkylated dextran (sephadex LH-20). Each packing material is evaluated based on the extent and time of separation and the cost of materials. The percent recovery in the bio-bead case is greater than 95 percent. Average molecular weights via vapor phase osmometry on the four sized fractions of the soluble SRC from bio-beads suggests that a separation according to molecular weight has been achieved. The description of a short tapered glass column to economically carry out these preparative separations is described.

6.5.22

ANALYSIS OF SOLVENT-REFINED COAL, RECYCLE SOLVENTS, AND COAL LIQUEFACTION PRODUCTS.

Schiller, Joseph E.
Grand Forks Energy Res Cent, ND
Am Chem Soc Div Pet Chem Prepr v 22 n 2 Mar 1977: Anal Chem of Tar Sands and Oil Shale, New Orleans, La., Mar 20-25 1977 p 638-655

Abstract: Analytical methods used for CO-Steam product characterization at GFERC were applied to solvent refined coals (SRC) and recycle solvents, as well as to coal liquefaction products. It is found that vigorous hydrogenation of coal increases the amount of oxygen compounds and decreases the amount of nitrogen compounds in distillable products. Mild hydrogenation gives dibenzofuran as the major oxygenated compound, while mainly hydroxyl compounds result from vigorous hydrogenation. The distillate from SRC #115R contains the intermediate between asphaltenes and oil in coal hydrogenation. In preparing SRC, solids separation prior to recycle solvent distillation may be a key factor in complete removal of solvent. 13 refs.

6.5.23

ANALYTICAL CHARACTERIZATION OF SOLVENT REFINED COAL COMPARISON WITH PETROLEUM RESIDUE

Callen, R.B.; Simpson, C.A.; Bendoraitis, J.G.

Mobil Res & Dev Corp, Paulsboro, NJ

Am Chem Soc Div Pet Chem Prepr v 22 n 2 March 1977; Anal Chem of Tar Sands and Oil Shale, New Orleans, La. Mar 20-25 1977 p 656-664

Abstract: In this study, gradient elution chromatography (GEC) has been employed to separate solvent refined coals, produced from three different coal sources, into well defined fractions. These fractions have been examined by C-13 and H-NMR techniques to gain some insight into the aromatic nature of the various fractions, and by infrared spectrometry to determine the nature of functional groups present therein. Particular attention has been paid to the distribution of heteroatoms N, O and S within the chromatographic cuts. Data from these SRC's are compared and contrasted to comparable data from a petroleum vacuum resid. 16 refs.

6.5.24

FULL-SCALE UTILITY BOILER TEST WITH SOLVENT REFINED COAL (SRC) TECHNICAL PROGRESS REPORT FOR THE PERIOD MARCH 1977

Richard D. McRanie

Southern Company Services, Inc. Birmingham, Alabama

July 14, 1977

Energy Research and Development Admin. FE-2222-4

Abstract: Three thousand tons of solvent refined coal (SRC), manufactured at a Pittsburg & Midway plant in Tacoma, Washington, were successfully shipped to and burned in a Georgia Power Company 22.5 MW coal-fired utility boiler.

The test demonstrated that SRC can be shipped in standard, open coal cars when treated with a commercially available coating spray to minimize blowing losses. Dust created in the conveyor system while loading and unloading the SRC can be controlled with a wetting agent spray.

SRC was stored, pulverized, and burned with only minor modifications to existing power plant equipment. No modifications were necessary to the coal conveying equipment or the coal storage bunkers. The pulverizers were modified only to the extent that cold primary air was used and ball spring pressure was reduced. The only boiler modification was the installation of water-cooled, dual register burners.

Emission tests were performed while burning SRC and demonstrated that SRC is an acceptable fuel for meeting current EPA New Source Performance Standards for SO₂ and NO_x. The particulate emissions were greater than anticipated due largely to unburned carbon, a common problem with boilers of this vintage (1946). The particulate problem can be handled with a modern precipitator.

(Cont'd)

Boiler efficiency tests were performed and indicate that efficiency when burning SRC is essentially the same as when burning coal.

SRC was shown to be an exceptional boiler fuel from an operating standpoint. Soot-blowers, which normally have to be used 6-12 times a day were not used at all during the 18-day test burn. The amount of flyash and bottom ash is significantly reduced. This will reduce ash system operating time and maintenance. The fact that SRC is brittle and easy to pulverize should reduce pulverizer maintenance.

6.6 SRC PRODUCT UPGRADING

Even though SRC is primarily looked upon as a clean utility fuel, upgrading SRC to hydrocarbon liquids and chemicals has received considerable attention. Organizations like Dow Chemical Company and Air Products and Chemicals, Inc. have published reports on their research on SRC from bituminous coals. University of North Dakota has published similar reports on solvent refined lignite. Montana State University published research on catalytic hydrogenation of coal-derived liquids. Stanford Research Institute and Montana State University have also reported on further processing of coal liquids.

6.6.1

H-COAL: CONVERSION OF WESTERN COALS

Johnson, C. A., Hellwig, K. C., Johanson, E. S., Wolk, R. H., Stotler, H. H.
Hydrocarbon Res Inst. Trenton, N.J.

Trans Soc Min Eng AIME v 254 n 3

Sep 1973 p235-238

Abstract: The H-Coal process, an ebullated bed reactor system for converting coal to liquid fuel, is described. Results from long-duration continuous flow bench-scale operations with Wyoming Wyodak, Arizona Black Mesa and Utah Kaiparowits Plateau coals are presented. Economic data on the conversion of these coals to liquid products are given. The potentials of the H-Coal process in regard to coal from western producers is stressed. 9 refs.

6.6.2

COAL: A PAST AND FUTURE KING

Squires, A. M.

Ambio v 3 n 1 1974 p 1-14

Abstract: Coal, used as a synthetic fuel, offers promise for filling the energy gap at reasonable power generation costs. Evaluated are fluidized-bed combustion to produce electricity by burning coal mixed with limestone; an advanced coal liquefaction system (the H-Coal process) that yields four barrels of oil per ton of coal as a pilot effort and a gasification process that substitutes oxygen for air. 20 refs.

6.6.3

"OIL FROM COAL" HOW SOUTH AFRICA'S SASOL PLANT OPERATES

Anon

World Min v 27 n 8 Jul 1974 p 48-50

Abstract: The Sasol plant, located at Sasolburg, So. Africa, converts annually 2 million tons of coal to 160 million gallons of gasoline, plus vast quantities of gaseous fuels, petrochemical and other co-products. The plant is based on processes developed in Germany and the United States and subsequently modified and improved by the present operators. Flow-sheet of the process is shown and described. No data are published on unit costs of the oil from coal activities but it is fair to say that it probably operates well below the \$10.00 per barrel estimate of United States companies for synthetic crude from coal because of the very low price coal available to it.

6.6.4

PRODUCTION OF LIQUID FUELS FROM COAL IN QUEENSLAND

Nicklin, D. J.

University of Queens, St. Lucia, Aust.

National Chemical Engineering Conference, 2nd, Proc. Surfers Paradise. Queens, Aust, July 10-12 1974, p 315-320. Published by Inst. of Chem. Eng., University of Queens, St. Lucia, 1974.

Abstract: Various processes for the manufacture of liquid fuels from coal are considered. Feasibility studies indicate that both the H-Coal process (direct hydrogenation) and the COED (Char Oil Energy Development) process would be economic at the current price of crude oil. It is argued that with our existing reserves of coal and oil we must eventually be prepared to develop the conversion technology. Further, because of the uncertain supply of crude oil and because of the lag in developing coal-to-oil technology, we should give serious consideration to a plant immediately. The COED process is in an advanced state of development, and seems to be well suited for Queensland. Cost considerations for both processes are included. 13 refs.

6.6.5

CONVERSION OF COAL TO OIL AND OTHER LIQUIDS AT BUREAU OF MINES

Harney, B. M.

Bureau of Mines, Dept. of the Interior, Washington, D.C.

Synthetic Pipeline Gas Symp. 6th, Proc, Chicago, Ill.

Oct 28-30 1974 p 119-133

Sponsored by Am Gas Assoc (Cat n L 51174), Arlington, Va. 1974

Abstract: The author reviews the Bureau of Mines coal liquefaction program which is aimed at the development of two promising coal conversion processes, Synthoil and Costeam, as well as improved economics. A program on refining synthetic fuel will determine data required for producing distillate products from synthetic crudes. Finally, a comprehensive program on support research and development will provide backup efforts needed for the liquefaction program with special emphasis on materials and equipment development and environmental analysis. 4 refs.

6.6.6

CHEMICALS FROM COAL. QUARTERLY PROGRESS REPORTS FOR THE PERIOD APRIL--DECEMBER 1974

Dow Chemical Co., Midland, Mich. (2196000)

Peters, B. C.

1974 18p

Contract: 14-32-0001-1534

Monitor: 18

Abstract: Further distillation and hydrocracking results on distillate fractions of coal-derived oils are reported for various hydrocracking conditions. Analytical techniques are being developed.

NTIS FE-1534-T-3

6.6.7

BATCH AUTOCLAVE HYDROGENATION OF SOLVENT REFINED LIGNITE

Low, J. Y. F., Klabunde, K. J., Severson, D. E., Woolsey, N. F., Baltisberger, R. J., Govek, M., Wolf, M. J., Rice, J., Switzer, S. T., Mannerling, M. L., Stenberg, V. I.

University of North Dakota, Grand Forks

8 refs.

American Chemical Society, Div. Fuel Chem., Prepr. 20/1/1975
122-142

Abstract: A research program has been developed at the University of North Dakota for the upgrading of Northern Great Plains Province Coals to premium fuels. The solid, low-melting product, solvent-refined lignite (SRL), has considerable potential for use as a clean burning solid fuel. However, due to its high reactivity, high solubility, low ash, and low sulfur, it is also a reasonable starting material for catalytic hydrogenation to clean liquid fuels. In this report a series of batch autoclave hydrogenation experiments on SRL are discussed. In these experiments the effect of variations in temperature, pressure, catalyst, and solvent medium are examined. The most important criterion has been the percent conversion of SRL to distillable liquids plus gases. The SRL and liquid fractions have also been carefully examined by spectroscopic and analytical chemical methods. It is demonstrated that optimal conditions for the highest conversion are the following: initial hydrogen pressure of 2500 PSI, 75 G of SRL, tetralin, presulfided HT-100 catalyst, at 450°C for 2 hours. A possibility of 90 percent conversion of SRL to distillable liquids and gases has been established.

6.6.8

CATALYTIC COAL LIQUEFACTION USING SYNTHESIS GAS

Fu, Y. C., Illig, E. G.

Pittsburgh Energy Res Cent, Pa.

Amer. Chem. Soc. Div. Fuel Chem. Prepr. v 20 n 1, 1975, for Meet, Philadelphia, Pa., Apr 6-11 1975, p 47-57

Abstract: The present work deals with an effort to develop an economical process for coal liquefaction-hydrodesulfurization using low cost synthesis gas in the presence of cobalt molybdate and sodium carbonate catalysts. While hydrogenation and desulfurization are catalyzed by cobalt molybdate, the water-gas shift reaction and reduction of coal by carbon monoxide are catalyzed by sodium carbonate. Hydrogen consumed is replenished partly during the hydrogenation by the following catalytic reaction, $\text{CO} + \text{H}_2\text{O}$ yields $\text{CO}_2 + \text{H}_2$. As a result, an effective hydrogenation is accomplished by eliminating large amounts of the oxygen in coal as carbon dioxide. It is noteworthy that the conversion of the oxygen in coal to water is one of the main hydrogen-consuming reactions in coal liquefaction. It is shown that high sulfur bituminous coal can be liquefied and desulfurized by hydrotreating with synthesis gas at 3,000 psi and 425° to 450°C in the presence of cobalt molybdate-sodium carbonate catalyst, steam, and recycle oil. 5 refs.

6.6.9

CHEMICALS FROM COAL. QUARTERLY PROGRESS REPORTS FOR THE PERIOD JANUARY--
JUNE 1975

Dow Chemical Co., Midland, Mich. (219000)

Peters, B. C.

1975 41p

Contract: E(49-18)-1534

Monitor: 18

Abstract: Laboratory studies in metal reactors aided by computer simulations are expected to provide comparative data from which preliminary capital requirements and operating costs can be estimated for a commercial plant which would use coal liquefaction products for the production of useful aliphatic and aromatic compounds. A sample of USBM Synthoil coal oil was obtained. Petrochemical processing experiments and data interpretation continued on FMC COED Syncrude and HRI H-Coal Oil. The COED Syncrude straight run mid-distillate was submitted to catalytic hydrocracking and steam coil cracking. The hydrocrackate was further hydrocracked and steam coil cracked. Trace metal analyses were reported for the straight run products. Initial straight run distillations of the H-Coal oil were completed along with steam coil cracking of the straight run naphtha. Hydrocracking of the straight run mid-distillate and further hydrocracking of the resulting hydrocrackate were completed. Additional mini-plant hydroprocessing reactors were completed, and considerable attention was given to improving in-house sulfur and nitrogen analytical techniques. COED Syncrude hydrocracking results were interpreted and experimental hydroprocessing of H-Coal Oil and Synthoil was conducted.

NTIS FE-1534-T-4

6.6.10

CHEMICALS FROM COAL. MONTHLY PROGRESS REPORTS FOR THE PERIOD JANUARY--
JUNE 1975

Dow Chemical Co., Midland, Mich. (2196000)

Peters, B. C.

1975 75p

Contract: E(49-18)-1534

Monitor: 18

Abstract: Laboratory studies in metal reactors aided by computer simulations are expected to provide comparative data from which preliminary capital requirements and operating costs can be estimated for a commercial plant which would use coal liquefaction products for the production of useful aliphatic and aromatic compounds. A straight run distillation of H-Coal oil and another hydrocracking run of a COED Syncrude fraction are reported. Trace metal analyses are given for COED Syncrude fractions. In-house analytical techniques were refined and will be included in various data compilations being prepared.

NTIS FE-1534-T-2

6.6.11

CHEMICAL CHARACTERIZATION, HANDLING, AND REFINING OF SRC TO LIQUID FUELS.
QUARTERLY PROGRESS REPORT, JUNE--SEPTEMBER 1975

Air Products and Chemicals, Inc., Allentown, Pa. (0131000)

Greskovich, E. J.

30 Sep 75 35p

Contract: E(49-18)-2003

Monitor: 18

Abstract: The objective of the research program is to characterize the inherent physical and chemical properties of solvent-refined coal (SRC) and to develop optimum methods for the desulfurization, denitrogenation, and hydrocracking of SRC using commercially available catalysts. The work plan consists of the following tasks: (1) literature survey; (2) chemical and physical characteristics of SRC and distillate materials; (3) handling characteristics of SRC; (4) design and construction of a test unit; (5) desulfurization and denitrogenation of SRC; and (6) hydrocracking studies

NTIS FE-2003-3

6.6.12

ANALYZING SYNCRUDE FROM WESTERN KENTUCKY COAL

Energy Research and Development Administration, Bartlesville, Oklahoma
Bartlesville Energy Research Center. (9501078)

Sturm, G. P. Jr., Woodward, P. W., Vogh, J. W., Holmes, S. A., Dooley, J. E.

Nov 75 31p

Monitor: 13

Abstract: A synthetic crude oil derived from western Kentucky coal by the charoil-energy development (COED) process was separated into two distillates and a residuum fraction. The lower boiling distillate was further separated by chemical extractions and chromatography and was characterized by gas chromatography and spectral techniques. The higher boiling distillate and the residuum were further separated and characterized largely by methods developed by the ERDA Energy Research Centers in Bartlesville, Oklahoma and Laramie, Wyoming, for characterization of heavy ends of petroleum. By adsorption chromatography the higher boiling distillate and residuum were separated into four concentrates: saturates, monoaromatics, diaromatics, and polyaromatic-polar. The saturate concentrates were characterized directly by mass spectrometry. The monoaromatic and diaromatic concentrates were further separated by gel permeation chromatography (GPC) before characterization by GPC-mass spectral correlations and nuclear magnetic resonance (NMR) spectrometry. After acid and base extractions the polyaromatic-polar concentrates were characterized in the same manner as the monoaromatics and diaromatics. Mass spectrometry was used to qualitatively analyze the acid and base extracts. Physical and
(cont'd)

chemical properties obtained by the ERDA routine crude oil analysis procedures complete the characterization data which are valuable for determining appropriate and efficient refining processes. The results obtained were similar to those for the Utah syncrude that was characterized by ERDA in a previous study and showed the syncrudes contained hydrocarbon types similar to those found in petroleum crudes. However, the syncrudes were more aromatic in character with substitution of shorter alkyl groups on the aromatic rings. They also contained appreciable amounts of oxygenates and had a fairly uniform distribution of nitrogen compounds across the boiling range.

NTIS BERC/RI-75/12

6.6.13

NEW ATHENS, ILLINOIS. WINNING SITE FOR COALCON'S WINNING TECHNIQUE OF CONVERTING COAL TO LIQUIDS AND GASES.

Chironis, N. P.

Coal Age v 80 n 13 Dec 1975 p 74-77

Abstract: An ERDA project calling for construction of a 2,600 -tpd demonstration plant that will convert high-sulfur coking coals to clean fuels and chemicals is described. Due for completion in 1980, the plant is expected to test Coalcon Company's unique process by converting 2,600 tpd of high-sulfur coal into 3,900 bpd of liquid fuels for use in boilers and 22 million cdf of high-Btu pipeline gas. The Coalcon facility will use a process called hydrocarbonization which promises higher conversion efficiencies and, therefore, lower costs than current technologies. In the process, pulverized coal is heated and reacted with hydrogen at temperatures of around 10000 F and at 500 psi pressure to produce the desirable liquid and gaseous fuels.

6.5.14

AROMATIC CHEMICALS FROM COAL

Schowalter, K. A., Petras, E. F.

US Steel Corp, Monroeville, Pa.

Coal Process Technol. v2 p 109-113 Published by AIChE, New York, N.Y. 1975

Abstract: A description is given of a process which combines coking and liquefaction techniques. The prominent features of the process are: (1) The production of high-quality metallurgical coke from a high-sulfur, high-ash coal not normally considered suitable for metallurgical purposes. (2) Production of substantial quantities of aromatics, other chemicals, and gaseous and liquid fuels which generate substantial co-product credits and could tend to reduce the demand for domestic natural gas and imported crude oil. (3) Production of coke in an "enclosed process offering substantial ecological advantages over the coke-oven route. Economic data is also presented. 1 ref.

6.6.15

CATALYTIC HYDROGENATION OF SOLVENT-REFINED LIGNITE TO LIQUID FUELS

Low, J. Y. F. (Univ. of N. Dakota, Grand Forks), Klabunde, K. J., Woolsey, N. F., Baltisberger, R. J., Govek, M., Stenberg, V. I.
Energy Sources 3/1/76 19-38

Abstract: Solvent-Refined Lignite (SRL) can be produced by treating lignite (Not dried) with CO-H₂, donor solvent and high temperature. This reactive black solid softens at about 150°C, is soluble in many organic solvents, is very low in ash and sulfur, and appears to be a good feedstock for further upgrading. Thus, a wide-ranging study was undertaken to determine the best reducing conditions for converting SRL to light distillable liquid fuels and/or chemical feedstocks. Batch autoclave studies were carried out in the temperature range of 375-450°C, hydrogen pressure range of 1500-4500 psi, with catalysts Ni-Mo-Al₂O₃, Co-Mo-Al₂O₃, Ni-W-Al₂O₃, Ni-W-SiO₂-Al₂O₃, SiO₂-Al₂O₃, Al₂O₃, SnO₂, and presulfided catalysts Ni-Mo-Al₂O₃, Co-Mo-Al₂O₃, Ni-W-Al₂O₃. Varying amounts of the solvents tetrahydrofuran, tetralin, naphthalene, and FS-120 petroleum fraction were also studied. Reductions without any solvent were studied too and were quite successful. The results were evaluated in terms of the amount of light liquids produced, deoxygenation, denitrification, hydrogen-carbon ratios, aromatic-aliphatic hydrogen ratios, and benzene solubility of unconverted material. Best results were obtained with a presulfided Ni-Mo-Al₂O₃ catalyst at 450°C, operating pressure of about 3500 psi with a 1:1 SRL-tetralin solvent ratio (90 percent overall conversion, approx, 20 percent light liquid (1), 15 percent light oil (2) 20 percent heavy oil (3 and 4) 10 percent unconverted). However, operating without any solvent also gave satisfactory results (88 percent overall conversion, 40 percent light liquid, 10 percent light oil, 10 percent heavy oil, 12 percent unconverted. Detailed gas chromatography-mass spectrometry (GC-MS) studies of selected liquid fractions indicate a high degree of aromaticity as tetralins, hydrophenanthrenes, and hydropyrenes.

6.6.16

LABORATORY STUDIES OF THE CONVERSION OF SOLVENT REFINED LIGNITE TO LIGHT LIQUID FUELS. PROJECT LIGNITE: PREMIUM FUELS

From Northern Great Plains Lignite. R and D Report No. 106,
Interim Report No. 3
Klabunde, K. J., Low, J. Y. F.
North Dakota University, Grand Forks (USA) Dept. of Chemistry
Contract E(49-18)-1224
Jan 16 1976
FE-1224-66

Abstract: Characterization studies of solvent refined lignite (SRL) and solvent refined coal (SRC), and the results of SRL and SRC conversions to lighter materials are described. The solubilities of SRL were determined in about forty organic solvents, several of which dissolved the SRL completely, the basic nitrogen and phenolic contents in the SRL were determined by potentiometric titrations. Some of the nitrogen in SRL comes from the solvent used in its preparation. From spectral studies, elemental analyses, (Cont'd)

and molecular weight determinations, some structural features of the average SRL molecule were deduced. Approximately 90 hydrogenation experiments were conducted for SRL and SRC conversion to gas and distillable liquid products using a standard set of reaction conditions for catalyst screening. Optimum conditions seemed to be 450°C with initial hydrogen pressures of 1800 PSI for non-solvent reactions and 2500 PSI with solvent. The best catalyst, in terms of overall conversion and denitrogenation, was presulfided NI-MO-Al₂O₃ which gave approximately 90 percent conversion of SRL to 10 percent gases and 80 percent distillable liquids. Almost equally high conversion was obtained with SRC using the same reaction conditions.

NTIS FE-1224-66

6.6.17

UPGRADING OF COAL LIQUIDS FOR USE AS POWER GENERATION FUELS. PHASE I REPORT

Mobil Research and Development Corp., Paulsboro, N.J.

Electric Power Research Inst., Palo Alto, Calif.

Bendoraitis, J. G., Cabal, A. V., Callen, R. B., Stein, T. R., Voltz, S. E.

Jan 76 132p

Project: EPRI-361-1

Monitor: EPRI-361-1

Abstract: This report describes the results of Phase I of a study on upgrading of coal liquids for use as gas turbine fuels. Samples of SRC (Solvent Refined Coal), H-Coal and Synthoil were investigated. The SRC and H-Coal were prepared from Illinois No. 6 Coal (Burning Star Mine), whereas the Synthoil was made from West Virginia coal (Pittsburgh Seam from Ireland Mine). The areas of work included the analytical characterization of coal liquids, their compatibility with selected petroleum fuels, estimation of potential turbine fuel specifications for coal liquids, and some exploratory process studies. The results of this study have shown that the physical properties and chemical compositions of coal liquids need to be improved to meet fuel specifications, and that some petroleum processing technology can be extended to accomplish the degree of upgrading required.

NTIS PB-252 939/4ST

6.6.18

CHEMICAL CHARACTERIZATION, HANDLING, AND REFINING OF SRC TO LIQUID FUELS. QUARTERLY PROGRESS REPORT, SEPTEMBER--DECEMBER 1975

Air Products and Chemicals, Inc., Allentown, Pa.
Energy Research and Development Administration. (0131000)
Greskovich, E. J.
Jan 5 76 118p
Contract: E(49-18)-2003
Monitor: 18

Abstract: The objective is to characterize the inherent physical and chemical properties of solvent refined coal (SRC) and to develop optimum methods for the desulfurization, denitrogenation, and hydrocracking of SRC using commercially available catalysts. A comprehensive survey of the available literature has been conducted to determine the chemical and physical properties of SRC and lower boiling coal-derived distillate materials. Pertinent analytical procedure which might be available for more thoroughly determining the product quality and handling properties of SRC are being evaluated. The literature on processing coal-derived liquids for removal of contaminants and for producing new materials is being reviewed. This review will include processing of heavy petroleum feedstocks to determine the applicability of such techniques to the processing of SRC. The literature on potential commercial catalysts for desulfurization, denitrogenation, and hydrocracking has been examined and selections for subsequent screening tests are being made. The bibliography is attached and includes sections on Liquefaction, Hydrotreating, Hydrocracking, Analysis, Properties and General Interest.

NTIS FE -2003-6

6.6.19

CATALYTIC HYDROGENATION OF COAL-DERIVED LIQUIDS. INTERIM REPORT, DECEMBER 1975--FEBRUARY 1976

Montana State Univ., Bozeman. Energy Research and Development Adm. (4307000)
Berg, L., McCandless, F. P.
Mar 76 31p
Contract: E949-18)-2034
Monitor: 18

Abstract: FMC Corporation's COED tar was hydrotreated in a flow-type reactor using cobalt molybdate on alumina as the catalyst to establish a base from which to measure the improvement of subsequent catalysts. When COED tar was treated with a nickel tungstate catalyst some change in the boiling range of the product was effected but no appreciable
(cont'd)

change in desulfurization occurred. The flow-type reactors for both the SYNTHOIL and the PAMCO liquefied coals have been constructed and tested. Experimental runs similar to those made with COED tar are scheduled to be carried out during the coming quarter.

NTIS FE-2034-2

6.6.20

CHEMICAL CHARACTERIZATION, HANDLING, AND REFINING OF SRC TO LIQUID FUELS. QUARTERLY PROGRESS REPORT, JANUARY--MARCH 1976

Air Products and Chemicals, Inc., Allentown, Pa. Corporate Research Dept. Energy Research and Development Administration. (9502375)

Greskovich, E. J.

Apr 6, 1976 67p

Contract: E(49-18)-2003

Monitor: 18

Abstract: Progress in determining the chemical composition and chemical and physical properties of samples of solvent-refined coal is reported. Thermogravimetric analyses and differential thermal analyses of several samples are given. The storage, weathering and materials handling behavior, including pneumatic transport of solvent-refined coal samples, was investigated. Equipment for desulfurization and denitrogenation of samples is being tested.

NTIS FE-2003-9

6.6.21

HOMOGENEOUS CATALYTIC HYDROCRACKING PROCESS FOR CONVERSION OF COAL TO LIQUID FUELS: BASIC AND EXPLORATORY RESEARCH. QUARTERLY REPORT NO. 2, FEBRUARY 1, 1976--APRIL 30, 1976

Mayo, F. R., Kirshen, N. A.

Stanford Research Inst., Menlo Park, Calif. (USA)

18 May 1976

Abstract: This task includes oxidations of 2-naphthoic acid, a pyridine-soluble extract of Illinois No. 6 coal, and the extracted and insoluble remainder of such coal, all by aqueous sodium hypochlorite at 30 to 50°C. The experiments with naphthoic acid show that the oxidation is pH-dependent, that the initial high rates of oxidation decrease much faster than the concentration of hypochlorite and that both rings of naphthoic acid are attacked, with some accompanying chlorination. The oxidation of a porous, pyridine-extracted coal by sodium hypochlorite at pH 9.0 to 9.2 proved to be surprisingly fast at 30°C, most of the sample going into solution in three hours. Oxidation of a water dispersion of a pyridine extract of the same coal at pH 10.0 to 10.5 was much slower at 50°C, for reasons not yet clear, but nearly all the extract eventually dissolved in the alkaline solution.

NTIS FE-2202-2

6.6.22

CHEMICALS FROM COAL. QUARTERLY TECHNICAL PROGRESS REPORT, JANUARY--MARCH 1976

Dow Chemical Co., Midland, Mich. Hydrocarbons and Energy Research Lab.
Energy Research and Development Administration. (9502218)

Peters, B. C.

30 Apr 76 19p

Contract: E(49-18)-1534 - Monitor: 18

Abstract: The Dow Chemical Company, under the sponsorship of ERDA, is studying the possibility of using coal-derived liquids as chemical feedstocks. Specifically, Dow is testing the liquids produced from four coal liquefaction processes (COED, SRC, SYNTHOIL, AND H-Coal) in standard petrochemical processing experiments and is evaluating these results to select one process for further study, based on process design, quality of chemicals produced, and overall plant economics. In this quarter, the COED hydrotreated naphtha was catalytically performed as had been done with the H-Coal hydrotreated naphtha. The naphtha fractions from each stage of the hydrocracking of COED mid-distillates were combined and hydrotreated. The hydrotreated product was then successfully performed. Hydrotreating of the combined H-Coal two stage hydrocrackate naphthas was begun. First pass hydrocracking of the Synthoil mid-distillate was completed, and second pass hydrocracking of the resulting hydrocrackate mid-distillate fraction was commenced. Various other petrochemical processing experiments are discussed briefly.

NTIS FE-1534-29

6.6.23

CATALYTIC HYDROGENATION OF COAL-DERIVED LIQUIDS. INTERIM REPORT, MARCH--MAY 1976

Montana State Univ., Bozeman. Energy Research and Development Adm. (4307000)
Berg, L., McCandless, F. P.

June 76 47p

Contract: E(49-18)-2034

Monitor: 18

Abstract: The investigation of the hydrotreating of COED tar with a nickel-tungsten catalyst showed that this catalyst is an improvement over cobalt molybdate in the production of lighter boiling product, that more lighter boiling product is obtained at the longer residence time and that sulfur removal from the product does not increase as the hydrogen rate is increased. Two runs were made on the hydrotreating of SYNTHOIL with cobalt molybdate catalyst to establish a basis for comparison with other catalysts. One run was completed with a nickel tungsten catalyst giving product boiling slightly lower than that obtained from cobalt molybdate. The hydrotreating of Solvent Refined Coal (SRC) was carried out in both continuous and batch reactors using the synthetic coal oil as a carrier solvent and employing a nickel tungsten catalyst. The higher pressure run gave a better conversion. The work to date on these three feedstocks indicates that temperature is a critical variable and should be maintained in a narrow range. In order to determine more quickly what is the optimum temperature for each catalyst and set of conditions, a few batch runs in a rocking bomb autoclave are being carried out on all three feedstocks prior to running the continuous feed hydrotreaters.

NTIS FE-2034-3

6.6.24

CHEMICAL CHARACTERIZATION, HANDLING, AND REFINING OF SRC TO LIQUID FUELS. ANNUAL REPORT, JUNE 1975--JUNE 1976

Air Products and Chemicals, Inc., Allentown, Pa. Energy Research and Development Administration.

Greskovich, E. J.

7 Jul 76 28p

Contract: E(49-18)-2003

Monitor: 18

Abstract: A bibliography relating to the characterization and refining of solvent-refined coal and coal-derived liquids has been prepared. Analyses and characterization tests of Wilsonville and Ft. Lewis SRC products show that they meet or exceed the low-ash, low-sulfur specifications. No significant inter- or intra-drum variations in composition occurred. Various analytical methods have been evaluated for use in characterizing SRC products: Brief results and sample data are given. The handling characteristics of SRC material are discussed: Agglomeration, sintering at or above 200°F, clogging of screens, consolidation and packing, grinding behavior, plugging burners, storage behavior, weathering, adhesion in pneumatic transport, etc. Finally, a unit is being constructed for desulfurization, denitrogenation and hydrocracking of SRC with solvent. Results of initial runs are reported.

NTIS FE-2003-12

6.6.25

CHEMICALS FROM COAL. QUARTERLY TECHNICAL PROGRESS REPORT, APRIL--JUNE 1976

Dow Chemical Co., Midland, Mich. Hydrocarbons and Energy Research Lab. Energy Research and Development Administration. (9502218)

Peters, B. C.

15 Jul 1976 16p

Contract: E(49-18)-1534

Monitor: 18

Abstract: Second pass hydrocracking of the USBM Synthoil mid-distillate was completed in April. Hydrocracking data for both the first and second pass hydrocracking are presented. Presulfiding procedures for the hydrotreating catalyst were changed, and the H-C B-1 + C-1 naphtha and the Synthoil B-1 + C-1 naphtha were each hydrotreated over American Cyanamid Aero HDS-9A catalyst. The Solvent Refined Coal product oils were recombined and distilled into the IBP-350°F naphtha hydrocracking, which is continuing.

NTIS FE-1534-33

6.6.26

HOMOGENEOUS CATALYTIC HYDROCRACKING PROCESSES FOR CONVERSION OF COAL TO LIQUID FUELS: BASIC AND EXPLORATORY RESEARCH. QUARTERLY REPORT NO. 3. MAY 1, 1976--JULY 31, 1976

Task 3B: Coal Structure Studies

Mayo, F. R., Kirshen, N. A.

Stanford Research Inst., Menlo Park, Calif. (USA)

15 Aug 1976

ABSTRACT: Further oxidations of fractions of Illinois No. 6 Coal by aqueous sodium hypochlorite have been carried out, mostly on the insoluble residue of pyridine extraction, which represents 83 percent of the coal and the most important part of the liquefaction and structure problems. Recoveries of products have been improved and anomalies found in the effects of pH on rates and products of hypochlorite oxidations. Solvent-Refined Illinois No. 6 Coal has been separated into Hexane-, toluene-, and pyridine- soluble fractions. These are compared with the corresponding fractions of the pyridine extraction of coal. The dehydrogenation of hydroaromatic to aromatic groups in coal appears to be important for structure studies by oxidation and an experiment with an SRC fraction has begun.

NTIS FE-2202-3

6.6.27

COMMERCIAL PLANT DESIGN FOR COAL HYDROCARBONIZATION

Ferritti, E. J.

Dravo Corp.

Coal Min Process v 13 n 8 Aug 1976

p 60-63, 72

Abstract: Study results for development of a conceptual design for a full-scale commercial plant utilizing the Coalcon hydrocarbonization process are outlined. Construction of a demonstration plant for this process is scheduled to begin next year under ERDA contract. The design basis for the ultimate full-scale plant will then be derived from all the design studies and the test results to achieve optimum economics and reliability. A number of favorable features and certain market conditions that make the Coalcon hydrocarbonization process attractive are discussed. For example, the process is noncatalytic and produces two main products, both of which are high-value forms of energy: (1) a clean liquid fuel, and (2) a high-Btu gas.

6.6.28
STONE & WEBSTER ENG. CORP., BOSTON, MASS.

Am Chem Soc Div Fuel Chem Prepr v 21 n 6 1976
Symp on Oil Shale, Tar Sands, and Related Mater \$EMDASH\$ Prod
and Util of Synfuels at 172nd National Meeting, San Francisco, Calif.
Aug 29-Sep 3 1976 p 190-197

Abstract: The present work forms part of an effort at Stone & Webster to assess how the production of olefins might be affected by changes in feedstock origin from petroleum to coal. In this paper the authors focus on experimental results concerning the characterization, hydrogenation, and pyrolysis of a coal-derived liquid: for comparison, data are also presented for the pyrolysis of a petroleum distillate, having a boiling range and hydrogen content similar to those of the coal liquid, as well as for pyrolysis of decahydronaphthalene, a model alicyclic substrate. Some economic implications of these results are reported separately; related work in progress includes theoretical and experimental study of alicyclic pyrolysis pathways. In experiments, samples of "Synthoil" coal liquid were used which is produced by USBM process. Results are tabulated and discussed in terms of reaction mechanisms possible. 6 refs.

6.6.29
CATALYTIC HYDROGENATION OF COAL-DERIVED LIQUIDS, INTERIM REPORT, JUNE 1976--
AUGUST 1976.

Berg, L., McCandless, F. P.
Montana State University, Bozeman (USA)
Evaluation of 21 catalysts for coed Tar, 18 for synthoil, and 20 for SRC
Contract E(49-18)-2034
September 1976

Abstract: Twenty-one different hydrotreating catalysts were evaluated with COED tar. The one that appeared to be the most effective of those tested was a 6 percent NiO-19 percent W on silica alumina, nickel on a alkaline support and nickel molybdenum on alumina also have merit. Eighteen different hydrotreating catalysts were tested with synthoil. The apparent best of these in making a lighter distillate fuel appears to be 10 percent WO₃ on activated alumina and 3 percent CoO-9 percent MoO₃ on alumina. Twenty different hydrotreating catalysts and/or reaction conditions were evaluated with solvent refined coal (SRC). Nickel tungstate catalysts were the most effective of those tested for cracking, desulfurization and denitrogenation. A slurry of 1:2 SRC to light oil appears to be the most attractive mixture to process.

NTIS FE-2034-4

6.6.30

CHEMICAL CHARACTERIZATION, HANDLING, AND REFINING OF SRC TO LIQUID FUELS. QUARTERLY PROGRESS RPT, JULY--SEPTEMBER 1976

Air Products and Chemicals, Inc., Allentown, Pa. Corporate Research
Dept. Energy Research and Development Administration. (9502375)

Greskovich, E. J.

25 Oct 1976 47p

Contract: E(49-18)-2003

Monitor: 18

Abstract: Work for the period July--September 1976 is summarized, and plans for future work on SRC characterization, handling, and refining are outlined. The main objective of the research program is to characterize the inherent physical and chemical properties of SRC and to develop optimum methods for the desulfurization, denitrogenation, and hydrocracking of SRC using commercially available catalysts.

NTIS FE-2003-15

6.6.31

LIQUEFY COAL TO PETROCHEMICAL FEED

Reber, S. A., Nadkarni, R. M., Hyde, R. W., Schutte, A. H., Stickles, R. P.
Arthur D. Little, Inc. Cambridge, Mass.

Hydrocarbon Process v55 n 11 Nov 1976 p229-234

Abstract: Liquefaction to upgrade coal to more desirable feedstocks of a more valuable fuel is of high interest. The Arthur D. Little (ADL) coal liquefaction process is described which uses coking to effect a clean separation, efficient use of hydrogen, low severity extraction and coking conditions, no mechanical separations, available hardware, no extraction catalyst and avoids high pressure slurry letdown. The process uses a hydrogen donor solvent under mild conditions for liquefaction and cracking and coking to separate overhead product vapor from coal ash and heavy coal extract. The economics are compared with the H-Coal and the Synthoil processes and potential for chemicals production is discussed. 15 refs.

6.6.32
COMBINATION COAL DEASHING AND COKING PROCESS

Bull, W. C., Bullough, V. L.
To Gulf Oil Corp.
Patent 12 claims
US Patent 3,997,422
Filed Date 20 Jun 1975
14 Dec 1976

Abstract: Deashed solid coal effluent from a coal solvent deashing process in which raw coal is converted to deashed solid and liquid coal is passed to a delayed coker. The coker operates at a higher temperature than is employed in the solvent deashing process and produces deashed coke. Liquid hydrocarbonaceous material including solvent boiling range liquid and hydrogen-containing gas. The hydrogen produced in the coker is derived from hydrogen which was previously consumed in the deashing step and can also include hydrogen contained in the raw coal. The solvent boiling range liquid and hydrogen produced in the coker are recycled to the solvent deashing step. Since the coker supplies a portion of the solvent required in the deashing step, the deashing step is operated to produce only a portion of its recycle liquid solvent requirement, thereby conserving hydrogen. 12 claims. 7 drawing figures.

6.6.33
UPGRADING COAL LIQUIDS TO GAS TURBINE FUELS -- COMPATIBILITY OF COAL LIQUIDS WITH PETROLEUM FUELS.

Cabal, Albert V.; Voltz, Sterline E.; Stein, Thomas R
Mobil Res & Dev Corp, Paulsboro, NJ
Ind Eng Chem Prod Res Dev v 16 n 1 Mar 1977 p 58-61

Abstract: The compatibility of three coal liquids with some petroleum fuels was determined. Synthoil and H-Coal were incompatible with No. 2 distillate fuel, No. 6 fuel oil, and heavy coker gas oil. Synthoil was compatible with clarified slurry oil (heavy product from catalytic cracking unit); H-Coal was incompatible. The 950 F-fractions of Synthoil and H-Coal were completely compatible with the petroleum fuels. Solvent Refined Coal was incompatible with all the petroleum fuels. The compatibility results are consistent with the molecular compositions of the coal liquids and petroleum products. 22 refs.

6.6.34

UPGRADING COAL LIQUIDS TO GAS TURBINE FUELS -- 3 EXPLORATORY PROCESS STUDIES.

Stein, Thomas R.; Voltz, Sterling E.; Callen, Robert B.

Mobile Res & Dev Corp, Paulsboro, NJ

Ind Eng Chem Prod Res Dev v 16 n 1 Mar 1977. p 61-68

Abstract: Exploratory process studies were conducted with samples of three coal liquids in a shaker bomb reactor. Blends of SRC with recycle solvent (from SRC process) or clarified slurry oil (from catalytic cracking process) are desulfurized and deoxygenated under hydroprocessing conditions. Removal of nitrogen is more difficult. Heteroatom removal is greater from H-coal and Synthoil than SRC blends under similar conditions. Some effects of hydro-processing on the chemical compositions of the coal liquids were determined. 16 refs.

6.7 EQUIPMENT DEVELOPMENT

Publications on equipment development includes a major report by Fluor Corporation on coal liquefaction design practices. Other papers cover filtration, slurry transport and pressure vessels. Even though the CSF process is not covered in this study, the reports on equipment evaluations at the Cresap pilot plant are included in this section because of their value to the SRC process design considerations.

6.7.1

FEEDING COAL TO PRESSURIZED SYSTEMS

Ferretti, E. J.

Blaw-Knox Chemical Plants Division, Dravo Corporation

Chemical Engineering (N.Y.) 81/26/9 December 1974. 113-161

Abstract: Slurry feed system, and dry system using pressurized-lock hoppers.

6.7.2

CERAMICS IN COAL CONVERSION

Schorr, J. R.

Battelle Columbus Labs., Ohio (USA)

1975

Workshop Proceedings on Ceramics for Energy Applications

Proceedings on Ceramics for Energy Applications

Columbus, Ohio, USA

24 November 1975

Abstract: An overview of the coal conversion environments in which ceramic materials play an important role is presented. Gasification takes a cumbersome-to-use, dirty solid fuel and transforms it into a convenient gaseous fuel or synthetic gas. Liquefaction usually involves the addition of a small percentage of hydrogen to the coal structure during its conversion into a clean, liquid fuel. In both of these processes, a portion of the heating value of the coal is expended to accomplish the conversion into a clean fuel. Of these two processes, gasification provides the harsher and more demanding environment. The emphasis is directed at gasification. Liquefaction does pose some wear problems and these are discussed. There is a wide variety of coal conversion processes under development. A recent listing described over 100 gasification and liquefaction processes known to be under active development. It is not possible to describe all of these but a few major processes under development in the United States which have reached the pilot plant stage are highlighted in order that a better understanding can exist as to how ceramic materials are important in the development and commercialization of these processes.

6.7.3

EVALUATION OF FILTRATION EQUIPMENT FOR CRESAP TESTING. SPECIAL REPORT.

Fluor Engineers and Constructors, Inc., Los Angeles, Calif.

Lewton, L. C.

July 75 71p

Contract: E(49-18)-1517

Monitor: 18

Abstract: Inherent in all current coal liquefaction processes is the requirement for removal, from the process stream, of solid particles down to colloidal size. This task becomes particularly difficult because of the high stream solids content and the severe temperature-pressure environment under which separation must be achieved. Among the potential solutions to the liquid-solids separation problem are three principal mechanical processes: hydrocloning, centrifugation, and filtration. Hydroclones are presently well understood and are installed at the Cresap plant. Centrifugation of coal slurries at Conso Synthetic Fuel (CSF) process temperature and pressure does not appear promising.

(Cont'd)

due to the stringent separation efficiency (99.9 percent) required and mechanical seal problems. Filters show promise. Therefore, a study was accomplished to determine which filter equipment, if any, should be considered for inclusion in the Cresap development test program. This report presents the results of this work and a recommended testing program.

NTIS FE-1517-16

6.7.4
HORIZONTAL CENTRIFUGE OPERATION FOR H-COAL LIQUID-SOLIDS SEPARATION

Hydrocarbon Research, Inc., Trenton, N.J. Research and Development Lab.

*Energy Research and Development Administration.

22 October 1975 52

Contract: E(49-18)-1544

Monitor: 18

Abstract: H-Coal products, from both syncrude and fuel oil mode operation, were centrifuged at up to 400°F in various experiments to develop information about ash removal. The results demonstrate the operability of the centrifuges tertial (Sharples P-850) and provide a basis for centrifuge design calculations. In most cases, 50 to 90 percent of the ash was removed from the liquid product, which amounted to roughly 75 to 90 percent of the fuel. Inorganic sulfur was more difficult to remove than the rest of the ash. Further, second pan runs showed that the ash material left in the product after the first pan was not removed as efficiently as the material removed in the first pans. Other trends are discussed.

NTIS TID-27061

6.7.5
PREVENTION OF FAILURES IN COAL CONVERSION SYSTEMS: PROCEEDINGS OF THE MEETING OF THE MECHANICAL FAILURES PREVENTION GROUP (24TH) HELD AT BATTELLE, COLUMBUS LABORATORIES, COLUMBUS, OHIO ON APRIL 21-23, 1976.

National Bureau of Standards, Washington, D.C. Metallurgy Div., *Office of Naval Research, Arlington, Va. *Federal Aviation Administration, Washington, D.C., *Energy Research and Development Administration, Washington, D.C., *Frankford Arsenal, Philadelphia, Pa.

Shives, T. Robert, Willard, William A.

April 77 237p

Rept. No: NBS-SP-468

Monitor: 18

Sponsored in part by Office of Naval Research, Arlington, Va., Frankford Arsenal, Philadelphia, Pa., Federal Aviation Administration, Washington, D.C., and Energy Research and Development Administration, Washington, D.C. Library of Congress Catalog Card No. 77-608043.

Abstract: These Proceedings consist of a group of twenty submitted papers and discussions from the 24th meeting of the Mechanical Failures Prevention Group which was held at Battelle, Columbus Laboratories in Columbus, Ohio
(Cont'd)

on April 21-23, 1976. Prevention of failures in coal conversion systems is the central theme of the Proceedings. A series of overview lectures dealing with reliability problems in coal conversion systems, economics of failures in energy generating systems, corrosion, and gaps in engineering data are presented. In addition, failure analysis, materials problems and related materials research are discussed. Some papers are accompanied by bibliography data. Each contribution is abstracted and indexed.

NTIS PB-265 552/OST

6.7.6

EVALUATION OF PROCESS PUMPS FOR CRESAP TESTING. SPECIAL REPORT

Fluor Engineers and Constructors, Inc., Los Angeles, Calif. *Energy Research and Development Administration.

Miles, E. J., Halleck, E. G.

Mar 76 27p

Contract: E(49-18)-1517

Monitor: 18

Abstract: Results are presented of a study to: (1) analyze the problems limiting durability of liquefaction process pumps; (2) define a test program for evaluating recommended improvements; and (3) specify configuration and material improvements for an acceptable commercial process.

NTIS FE-1517-31

6.7.7

EVALUATION OF THE USE OF EXISTING CRESAP PILOT PLANT VESSELS FOR DEVELOPMENT TESTING. SPECIAL REPORT

Fluor Engineers and Constructors, Inc., Los Angeles, Calif. *Energy Research and Development Administration

April 76 32p

Contract: E(49-18)-1517

Monitor: 18

Abstract: The design considerations for and operating characteristics of, certain pressure vessels and bins installed at the Cresap Coal Liquefaction Pilot Plant are discussed. The equipment items discussed are: coal feed bins; slurry mix tanks; coal extraction reactor vessel; and a carbonization reactor vessel. Each equipment item is described and its operational history at the Cresap plant is briefly outlined. The major vessel design considerations, encountered in attempting to scale these equipment configurations up to full scale plant size, are summarized. Some design concepts for such a scale-up are also presented. Areas for further investigation are indicated where deemed appropriate.

NTIS FE-1517-26

6.7.8

EVALUATION OF CSF PROCESS EXTRACTOR PERFORMANCE IMPROVEMENT FOR CRESAP TESTING. SPECIAL REPORT

Fluor Engineers and Constructors, Inc., Los Angeles, Calif. *Energy Research and Development Administration.

April 76 36p

Rept No: FE-1517-1800/01

Contract: E(49-18)-1517

Monitor: 18

Abstract: The CSF extractor is a vertical pressure vessel 24 inches in diameter and approximately 25 feet tall. A shaft equipped with mixing turbines rotates inside the extractor vessel to provide an intimate contact between coal fines and solvent. The operating conditions within the vessel are 750°F and 400 psig. Among the numerous mechanical problems encountered in this units, the following items represent the greatest obstacles to continuous operation: shaft packing failure; coke formation in the vapor zone of the extractor; and bearing failures. Methods for improving the operational life of the CSF Process extractor unit as installed in the Cresap Coal Liquefaction Pilot Plant have been evaluated. Both external bearings and internal bearings with improved wear characteristics were considered. The study resulted in the design of a preferred external bearing concept. A test program to evaluate and refine the external bearing concept was developed.

NTIS FE-1517-33

6.7.9

EVALUATION OF HEAT EXCHANGERS FOR CRESAP TESTING

Fluor Engineers and Constructors, Inc., Los Angeles, Calif. *Energy Research and Development Administration

Ellefson, L. C.

April 76 44p

Contract: E(49-18)-1517

Monitor: 18

Abstract: Inherent with all coal liquefaction processes are streams containing coal-derived heavy hydrocarbons and slurries of solid coal particles. The solid particles in the coal slurries (coal, silicate, and ash) cause erosion, corrosion and fouling of heat exchangers. These high rates of erosion and corrosion cause rapid deterioration of the tubes. The flow media can polymerize and foul the tubes ultimately plugging them and thus lowering the performance of the heat exchangers. For the optimum design of heat exchangers, the parameters which must be considered are erosion-corrosion rates; the fouling characteristics; the solid particle settling velocity; pressure drop; and the heat transfer coefficients of the fluids flowing through the heat exchanger. A study was performed to evaluate streams which should be investigated to obtain the desired heat exchanger design data. The results of this evaluation are presented along with a recommended test program.

NTIS FE-1517-28

6.7.10

EVALUATION OF FIRED HEATERS FOR CRESAP TESTING

Fluor Engineers and Constructors, Inc., Los Angeles, Calif. *Energy Research and Development Administration.

May 76 25p

Contract: E(49-18)-1517

Monitor: 18

Abstract: Coal liquefaction processes require a fired heater to heat the coal and solvent slurry mixture. A flash still preheater may also be necessary to provide the heat of vaporization required for the recovery of solvent from heavy oils. Both of these critical applications call for special attention to unique requirements for commercial plant design. These heaters operate at process conditions approaching coking temperatures of the coal particles and the heavy coal extract. Operating and maintenance costs can be adversely affected by above normal fouling of the heater tubes. The economical design of commercial units requires careful trade-offs between heat transfer area, heater life, maintenance requirements, and thermal efficiency. A test program to determine the region of fired heater design and operability is desirable. This study has been conducted to evaluate which critical fired heater services common to coal liquefaction processes should be included in the fired heater development test program at Cresap.

NTIS FE-1517-25

6.7.11

COAL LIQUEFACTION DESIGN PRACTICES MANUAL. FINAL REPORT

Fluor Engineers and Constructors, Inc., Los Angeles, Calif. *Electric Power Research Inst., Palo Alto, Calif.

Kimmel, S., Levy, D., Michalski, P., Pack, G., Simbeck, D.

July 76 352p

Project: EPRI-409-1

Monitor: EPRI/AF-199

Abstract: This manual, on project 409-1, assembles existing liquefaction equipment and operating history from the German pre-WWII days to the present. Considerable experimental and design effort has been expended over this period throughout the world on a variety of coal liquefaction programs. An open exchange of information has not occurred that would permit all investigators to contribute to and benefit from the experience of others. In many cases, the same mistakes have been made over and over again. It is hoped that this equipment manual will be the start of an on-going equipment record so the new engineers in the field can readily benefit from previous experience. It is anticipated that periodic up-dating will be required to keep the record current and useful.

NTIS PB-257 541/3ST

6.7.12

MATERIAL CHALLENGES OF COAL LIQUEFACTION

O'Hara, J. B.; Lochmann, W. J.; Jentz, N.E.

Ralph M. Parsons Co. Pasadena, Calif.

Chem Eng (NY) v 84 n 8 Apr 11 1977 p 147-148, 150, 152, 154

Abstract: This paper discusses some design aspects of chemical plants for coal liquefaction. A key effort needed to reach this goal is the development and selection of materials for commercial plants that will be large, efficient, and highly capital intensive. (Plants processing 20,000 to 40,000 tons of coal per day will likely be in the billion-dollar class. The subject is considered under headings: liquefaction process types, hydroliquefaction materials needs; sulfur and sulfur compounds, hydrogen attack; chlorides and stress corrosion cracking; extraction processes, pyrolysis; and indirect liquefaction. 14 refs.

6.7.13

EROSION PROBLEMS IN LETDOWN VALVES.

Mueller, J. J.

Battelle - Columbus, Ohio

Natl Bur Stand Spec Publ n 468 Apr 1977; Prev. of Failures in Coal Convers.

Proc of Meet of Mech Failures Prev Group. 24th, Columbus, Ohio

Apr 21-23 1976 p 107-120

Abstract: This paper is concerned with the equipment wear caused by the coal-derived slurries associated with all types of coal liquefaction processing. The throttling valves used to let down the ash-containing slurry from the high processing pressure to near-ambient pressure experience relatively short service life as a result of erosion wear of the internal components. Design modifications are continually being made to minimize the wear problem and thereby lengthen the time between component changes. The design of trim components is discussed and examples are presented of worn components and some of the valve design modification which have been evaluated. Wear of the critical cemented carbide trim components is shown to occur by the mechanism of removal of the soft metal matrix from between the hard, wear-resistant carbide particles, and the associated pullout of the hard particles. Improvement in the life of trim components is expected to come with minimized metallic binder content or adoption of hard, single-phase ceramic materials.

6.7.14

OVERVIEW OF EQUIPMENT FOR COAL CONVERSION

Lochmann, W. J.; Howell, R. D.
Ralph M. Parsons Co., Pasadena, Calif.
Hydrocarbon Process v 56 n 5 May 1977 p 197-199

Abstract: For viable coal conversion plants to be constructed and operated reliably, the corrosion engineer will be challenged as in few other industries. Simple substitution of more corrosion resistant materials in currently designed equipment is no longer adequate. For various equipment items, the submitted overview presents programs proposed or already under way in which corrosion engineers and designers interface for the construction of coal conversion plants. The following pieces of equipment are discussed: pressure vessels; piping; valves; pumps; turbines; heat exchangers; fired heaters; instrumentation; hydrocyclones and cyclones.

6.7.15

EQUIPMENT NEEDS IN COAL GASIFICATION AND LIQUEFACTION PLANTS

Ingersoll-Rand Research, Inc.
Worthen, Richard
Presented at 4th Annual International Conference on Coal Gasification,
Liquefaction and Conversion to Electricity
University of Pittsburgh, Pittsburgh, Pa.
4 Aug 1977

Abstract: The purpose of this paper is to summarize several areas in coal gasification and liquefaction plants requiring equipment development in order to achieve the improved equipment development in order to achieve the improved equipment reliability that is required for the demonstration plant program. Specifically, the equipment of interest are dirty gas expanders, compressors and slurry pumps.

6.8 PROPERTIES OF RAW COAL, INTERMEDIATE PRODUCTS AND PROCESS STREAMS

Coal derived asphaltenes, mineral matter benzene insolubles components, etc. in coal liquids have been the subject of several papers listed in this section. Information on the properties of various process streams and byproducts of SRC process are sorely lacking as evidenced by a very few published papers on this subject. There is a larger amount of information of this nature in the Wilsonville and Fort Lewis Pilot Plant reports. However, this needs to be organized and published in a better form.

6.8.1

THE NATURE AND ORIGIN OF ASPHALTENES IN PROCESSED COALS

Mobil Research and Development Corp., Princeton, N.J.
Central Research Div. Electric Power Research Inst., Palo Alto, Calif.

Annual Report

Whitehurst, D. D., Farcasiu, M., Mitchell, T. O.

Feb 76 236p

Project: EPRI-410-1

Monitor: EPRI/AF-252

Abstract: This report presents the results of the first year of a two-year effort aimed at obtaining a fundamental understanding of the chemical nature and structure of solubilized coals and the kinetics and mechanisms by which these liquefaction products are formed from various coals under solvent refinishing (SRC) conditions. Coal liquefaction was studied under somewhat mild reaction conditions and at very low conversions, as well as under conditions typical of SRC pilot plant operations in order to be able to follow the solubilization process more closely. A much more detailed investigation of the skeletal structures and chemical functionality of products was pursued than has previously been performed.

NTIS PB-257 569/4ST

6.8.2

METHOD FOR THE DETERMINATION OF BENZENE INSOLUBLES, ASPHALTENES, AND OILS IN COAL-DERIVED LIQUIDS

Energy Research and Development Administration, Pittsburgh, Pa.
Pittsburgh Energy Research Center.

Mima, M. J., Schultz, H., McKinstry, W. E.

Sep 76 17p

Monitor: 18

Abstract: The details are presented of the method used for the solvent analysis of coal-derived liquids. The method is used to determine the benzene insoluble (unreacted or partially reacted coal), the benzene soluble-pentane insoluble (asphaltenes), and the benzene soluble-pentane soluble (oils) fractions of coal-derived liquids. Since the procedure described uses benzene and n-pentane as solvents to analyze coal-derived liquids, safety precautions must be observed carefully. Strict adherence to the described procedure is necessary to insure that the conditions of solvent treatment are uniform and to obtain the desired degree of precision.

NTIS PERC/RI-76/6

6.8.3

CHEMICAL NATURE OF THE BENZENE INSOLUBLE COMPONENTS OF SOLVENT REFINED COALS

Farcasiu, M., Mitchell, T. O., Whitehurst, D. D.
Mobil Research and Development Corp., Princeton, N.J.
12 Refs.

Am. Chem. Soc., Div. Fuel Chem., Prepr. Jul 21 1976 11-26
American Chemical Society Meeting
San Francisco, California
Aug 29 1976

Abstract: The chemical nature of soluble products of coal produced via noncatalytic solvent refining processes have been investigated. A detailed chemical characterization of the fractions that are insoluble in benzene revealed that they are to be distinguished from hexane soluble (hydrocarbons and ethers) and benzene soluble (mono functional compounds) primarily by their higher degree of functionality and not by aromatic content or molecular weight. The higher functionality is primarily in the form of more -OH groups per molecule. Accordingly, the name asphaltols is proposed for these materials. As a class, asphaltols have greater than 7 wt percent O and their aromatic carbon content and degree of aromatic ring condensation are low (similar to that of the parent coal). When coal is converted at short contact times (0.5 to 3 min) asphaltols are the predominant products, often representing as much as 70 to 80 wt percent of the original coal. In the absence of hydrogen donor solvents asphaltols as a class produce greater than 70 wt percent char at greater than 400° C. In the presence of hydrogen donor solvents, asphaltols are converted to less functional (benzene-soluble and hexane-soluble) materials in a parallel fashion. Relationships between the chemical structure and functionality of the asphaltols, their reactivity, and their origin are discussed.

6.8.4

X-RAY AND DERIVATOGRAPHIC EXAMINATIONS OF COAL EXTRACT AND ITS BENZENE-INSOLUBLE COMPONENTS

Tengler, S. (Instytut Chemii Wyzszej Szkoły Pedagogicznej, Kielce, Poland)
Hodorowicz, S.

14 Refs.

Koks, Smola, Gaz 21/21/oct 1976

Abstract: X-Ray and derivatographic examinations were carried out of anthracene coal extract and of isolated benzene-insoluble components (α_1 + α_2). It was found that the extract investigated and its group components α_1 + α_2 constitute a heterogeneous system of organic connections forming structures of the graphite type and aggregates with privileged distance of lattice planes of about 5 Å. It was shown that both in the extract and in its benzene insoluble matter at elevated temperatures emerge endo- and exothermic effects from oxidation, decomposition and distilling off processes of some components.

6.8.5

HIGH PRECISION TRACE ELEMENT AND ORGANIC CONSTITUENT ANALYSIS OF
OIL SHALE AND SOLVENT-REFINED COAL MATERIALS

Fruchter, J. S., Petersen, M. R., Lall, J. C., Ryan, P. W.
Battelle Pacific Northwest Labs., Richland, Washington (USA)
Contract EY-76-C-06-1830
Nov 1976
Conf-770301--10
173. National Meeting of the American Chemical Society
New Orleans, Louisiana, United States of America (USA)

Abstract: The application of a number of sensitive and precise methods for the determination of trace elements, heavy element species and organic compounds in materials from an oil shale research retort process and from a solvent-refined coal pilot plant operation are discussed. The methods were chosen both for their sensitivity, and also for their relative freedom from interference effects. Coal liquids contain much higher concentrations of aromatic compounds, including polynuclear aromatic hydrocarbons (PNA'S). A larger relative fraction of the PNA'S in shale oil are alkyl substituted. Coal liquids are also considerably higher in phenols (28 percent) than is shale oil (2 percent). N-heterocyclics are present in higher concentration (greater than 8 percent) in shale oil due to the high nitrogen content of the raw shale. Hydroaromatics are common in coal liquids but negligible in shale oil. Inorganic elements and speciation measurements indicate significant amounts of the toxic heavy elements Hg,As,Zn. and S in effluent oil water and gas streams. In addition, the process water contains significant Co,Br,Sb. and U. Raw oil shale is highly enriched in Se,As and Sb and somewhat enriched in U,Pb.Cs.Hg and Zn. Solvent-refined coal liquids were found to be relatively low in most trace elements. The majority of trace elements are concentrated by the process into the mineral residue. Only Br and Hg are not depleted in solvent-refined coal. Other trace elements still remaining in significant amounts are U,Ta,Cr, and Zn.

6.8.6

CHEMISTRY AND STRUCTURE OF COAL-DERIVED ASPHALTENES, PHASE II. QUARTERLY
PROGRESS REPORT, JULY--SEPTEMBER 1976

California University, Los Angeles. Energy Research and Development
Administration. (1144000)
Yen, T. F.
1976 32p
Contract: E(49)-18)-2031
Monitor: 18

Abstract: Additional elemental analyses and molecular weight determinations have been carried out on the various components of the solvent fractionated coal liquids from the three direct general processes for coal liquefaction. The atomic C/H ratios are found to increase in the direction carboid greater than asphaltene greater than coal. Completed chromatography of asphaltenes
(cont'd)

on silica gel and Amberlyst-15 indicates that basic and non-basic asphaltene components may be separated into two major fractions by this method. This offers an alternative to the use of dry HCl which may introduce chlorine chemically into at least one of the separated components. A preliminary correlation has been observed between the color index, I, and the number of aromatic carbons per average molecule of asphaltene and carboid. Carbon aromaticity values, f_a , determined directly by the exp ^{13}C -NMR method have been found to be 0.07 ± 0.01 higher than those previously determined by the x-ray method for asphaltenes. Mass spectroscopy at 16 and 70 ev has been used to obtain spectra believed to represent the envelope of asphaltene parent peaks, and the envelope of asphaltene fragment peaks formed by either alpha or beta elimination with the latter predominant.

NTIS FE-2031-5

6.8.7

CHARACTERIZATION OF MINERAL MATTER IN COALS AND COAL LIQUEFACTION RESIDUES. EPRI PROJECT RP 366-1 - QUARTERLY REPORT SEPTEMBER, 1976 - DECEMBER, 1976

The Pennsylvania State University, University Park, Pa.

Abstract: The major aspects of this report are detailed below.

Optical Microscopy - A re-evaluation has been made of the classification of components found in the HRI filter cake residues. Characterizations of Wilsonville reactor solids have continued, and descriptions are made of some of these solids derived from West Kentucky 9/14 runs. In general, they are composed of mineral matter (predominantly pyrrhotite) and a coke breeze.

Mineralogical Analyses - A brief description is made of the new Fourier Transform Infra-red method of analyzing mineral mixtures which is being developed in these laboratories. It is thought that this procedure will lead to more rapid and consistent analyses of LTA.

Partical Size Analysis - A particle size analysis is reported for a filter blinding material (Wilsonville) from a West Kentucky 9/14 liquefaction run.

6.9 ENVIRONMENTAL CONCERNS

Considerable effort is being devoted to identify and abate solid, liquid and gaseous pollutants during the manufacture of SRC. Consulting firms like Booz-Allen and Hamilton and Hoffman Associates have published sponsored studies. Pittsburg and Midway and Battelle have published studies based on laboratory data on process streams. One of the major environmental concerns is the possible effect of SRC plants will have on water resources as brought out in several papers. Sulfur and nitrogen balances, as well as organic constituents in process streams, are dealt with in several papers. Exxon R&D Company and M. W. Kellogg have published very useful papers.

6.9.1

STUDY OF COST OF SULPHUR OXIDE AND PARTICULATE CONTROL USING
SOLVENT REFINED COAL

Shaver, R.G.

Contract PHS-CPA--22-69-82

Apr. 1970

CFSTI PB-193420

6.9.2

PROPOSED PILOT PLANT, FORT LEWIS, WASHINGTON

Office of Coal Research, Washington, D.C.

Final environmental impact statement

27 Sep 71 40p

Supersedes report dated 30 Apr 71, PB-198 861-D

Abstract: This environmental statement related to a pilot plant proposed for erection at Fort Lewis, Washington. This plant would research solvent refined coal (SRC) and be in operation for a period of 2 or 3 years. Ultimately the plant will be declared surplus and sold. If no other use can be found for it, the plant will be torn down. This pilot plant, as designed, should create no environmental problems. In the case of malfunction, the threat of which is minimal, the plant will shut down until it meets environmental requirements.

NTIS PB-198 861-F

6.9.3

CONTROLLING SO₂ EMISSIONS FROM COAL-BURNING BOILERS: STATUS REPORT

Tiernan, J. W.

Mining Eng./24/8/AUG 1972

47-55

6.9.4

SYMPOSIUM ON ENVIRONMENTAL POLLUTION CONTROL

Hamersma, J.W., Kraft, M.L., Koutsoukcs, E.P., Meyers, R.A.,
Lorenzi, L., Jr., Janes, T.K., Land, J.S., Shaver, R.G., Archer, D.H.,
Qadar, S.A., Hill, G.R., Gregoli, A.A.

Amer. Chem. Soc., Div. Fuel Chem., Prepr. 17/2/27 Aug. 1972

121p.

6.9.5

ENVIRONMENTAL PROTECTION OF LARGE SCALE COAL REFINING AND MINING
OPERATIONS. MONTHLY PROGRESS REPORTS, June 11-December 31, 1973

Hittman Associates, Inc., Columbia, Md
1973 152p

Abstract: A 1000-Mw coal-burning electric power complex in the north mid-western U.S. is considered which (1) burns as-mined coal (lignites or sub-bituminous) with stack gas cleaning, or (2) burns as-mined coal with fluidized-bed combustion, or (3) burns low-Btu SNG, or (4) uses solvent-refined coal. Possible coal reserve areas are studied, land and water requirements estimated and gaseous and liquid effluents and leachants from ashes or slag are considered. Environmental effects of the complex on ground water, irrigation water, reservoir location, wild life, fish, trees, shrubs, snakes, etc. are investigated for some 15 large coal deposits.

NTIS FE-1508-T-3

6.9.6

EMISSIONS FROM PROCESSES PRODUCING CLEAN FUELS

Booz-Allen and Hamilton, Inc., Bethesda, MD. Environmental Protection Agency, Research Triangle Park, N.C. Office of Air Quality Planning and Standards

Final Report

Glazer, F., Hershaft, A., Shaw, R.

Mar 74 446p

Rept. No.: BA-9075-015

Contract: EPA-68-02-1358

Monitor: EPA/450/3-75/028

Abstract: The objective of the research effort described in this report was to assess the technical feasibility and to estimate the costs of installing alternative pollution control systems on clean-fuel processes which are likely to become commercially viable within the next decade. The intent was not to establish standards but rather to: Determine the types and estimated amounts of pollutants generated in clean-fuel processes; Determine the degree of availability processes for minimizing emissions from these processes; Estimate the economic and energy costs for control of these emissions; Indicate possible means for utilizing the by-products from these processes in environmentally satisfactory ways. The primary emphasis in the study was placed on the control of sulfur emissions, although other pollutant streams were considered and evaluated as well.

NTIS PB-245 671/3ST

6.9.7

EMISSIONS FROM PROCESSES PRODUCING CLEAN FUELS

Booz-Allen and Hamilton, Inc., Bethesda, Md. Environmental Protection Agency, Research Triangle Park, N.C. Office of Air Quality Planning and Standards

Final Report

Glazer, F., Hershaft, A., Shaw, R.

Mar 74 447p

Report No: 9075-015

Contract: EPA-68-02-1358

Monitor: EPA/450/3-75/028

Abstract: Processes for converting coal, oil and shale to clean fuels were studied. Most of the processes considered have not yet been developed to commercialization. Based on preliminary data and engineering estimates developed, it can be concluded that: (1) unit processes apparently exist to provide adequate control of most waste streams from clean-fuel plants, although some pollutants remain difficult to treat; (2) the pollutant emissions from clean-fuel processes

(cont'd)

will, in general, be relatively low when compared to emissions from alternative uses of the raw fuel; (3) the total costs of pollutant control (1973 basis) for achieving low levels of plant emissions, in high-Btu coal gasification processes, range from 15 to 30 cents per million Btu and can be expected to increase in proportion to the severity of the emission controls required; (4) low-Btu gasification followed by desulfurization may be considered as a pollution control system because it permits the combustion of coal with decreased emissions. In that case, the overall cost of pollution control is about \$0.65/10 to the sixth power Btu of gas produced.

NTIS PB-247 40/8ST

6.9.8

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL. VOLUME I. ENGINEERING STUDIES. PART 4. IMPACT OF THE SOLVENT REFINED COAL PROCESS

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.

Interim Report Mar 73-Oct 73

Apr 74 94p

Contract: DI-14-01-0001-496

Monitor: OCR-53-INT-5

Prepared in cooperation with Carnegie Mellon Univ., Pittsburgh, PA

Abstract: The report is a summary evaluation of the effect of location and environmental regulations on the solvent refined coal (SRC) process. The purpose of the work was to facilitate commercial realization of the SRC process by anticipating marketing and environmental problems which would be faced by an operator of an SRC plant. The report describes a model which is designed to optimize location of an SRC plant in relation to the source of coal and the market for the fuel product while considering the effect of 19 variables. The report also includes a compilation of environmental regulations with which an SRC plant would have to comply.

NTIS PB-234 038/8

6.9.9

ENVIRONMENTAL ASPECTS OF COAL LIQUEFACTION

Bureau of Mines, Pittsburgh, Pa. Energy Research Center

Yavorsky, P. M., Akhtar, S.

26 April 1974 13p

6.9.10

EVALUATION OF R AND D INVESTMENT ALTERNATIVES FOR SO_x AIR POLLUTION CONTROL PROCESSES

Kellogg (M. W.) Co., Houston, Tex. National Environmental Research Center, Research Triangle Park, N.C. Control Systems Lab.

Final Report Oct 72-Dec 73

Shore, D., O'Donnell, J. J., Chan, F. K.

Sep 74 288p

Contract: EPA-68-02-1308

Project: EPA-ROAP-21ADE-029

Monitor: EPA/650/2-74-098

Abstract: The report presents data on sulfur oxide (SO_x) emissions from five major source groups: utility plants, industrial boilers, non-ferrous smelters, sulfuric acid plants, and sulfur (Claus) plants. For all source groups studied, the bulk of the SO_x emissions comes from a relatively small number of the largest plants. The report also includes evaluations of several different sulfur control systems, including stack gas scrubbing (wet limestone process and Wellman/Allied System), substitute natural gas, solvent refined coal, Lurgi gasification with a combined power cycle, and pressurized fluidized-bed combustion with a combined power cycle. Process and cost models and/or economics are presented for each system. Cost models for the stack gas scrubbing processes were applied to existing utility plants in the U.S. and the results analyzed.

NITS PB-238 263/85T

6.9.11

ENVIRONMENTAL FACTORS IN COAL LIQUEFACTION PLANT DESIGN

Parsons (Ralph M.) Co., Los Angeles, Calif. Office of Coal Research, Washington, DC (277 100)

O'Hara, J.B., Rippee, S.N., Loran, B.I., Mindheim, W.J.

14 May 74 24p

Contract: DI-14-32-0001-1234

Monitor: OCR-82-INT-3

Abstract: Environmental factors will play an important role in design and operation of coal liquefaction plants. Such plants are a major

(cont'd.)

national goal and the first large units could be built during this decade. Proposed treatment methods are discussed for solid, liquid, and gaseous effluents based on a preliminary liquefaction plant design. An approach to noise control procedures designed to satisfy requirements of the Occupational Health and Safety Act is also described in this report.

NTIS PB-235 802/6

6.9.12 ENVIRONMENTAL ASPECTS OF SOLVENT REFINING

Harrison, W. B.
Southern Services, Inc., Birmingham, Al.
Oct 1974
Symposium Proceedings: Environmental Aspects of Fuel Conversion
Technology, Ayer, F. A. (Comp.)
St. Louis, Missouri
13 May 1974

6.9.13 SYMPOSIUM PROCEEDINGS: ENVIRONMENTAL ASPECTS OF FUEL CONVERSION TECHNOLOGY (MAY 1974, ST. LOUIS, MISSOURI)

Research Triangle Inst., Durham, N.C. National Environmental Research
Center, Research Triangle Park, N.C. Control Systems Lab (304 400)

Final Report
Ayer, Franklin A.
Oct 74 356 p
Contract: EPA-68-02-1325
Project: EPA-ROAP-21ADD, PA-ROAP-21AFJ
Monitor: EPA/650/2-74-118

Abstract: This document is the final report covering EPA's symposium to review and discuss environmentally related information of coal conversion technology. More specifically, papers were presented that covered environmental quality and standards, fuel contaminants, environmental aspects of specific fuel conversion systems, fuel utilization and total environmental assessment, and research and development needs.

NTIS PB-238 304/OST

6.9.14

ILLINOIS COAL AND WATER RESOURCES FOR COAL CONVERSION PLANTS

Smith, W.H.; Prickett, T. A.

Illinois State Geological Survey

Source: Proc Ill Mining Inst 1974, for 82nd Annual Meeting,
Springfield, Ill, Oct 3-4 1974 p68-80

Abstract: Seven broad classifications of water resources in Illinois were investigated to locate areas which could support the expected 6 to 72 million gallons per day range of consumptive water use for coal gasification plants. In total, nearly 300 sites were located. The next step in this overall effort will be to superpose the water, and coal resources being delineated by the Geological Survey, to find the best combination for coal gasification plant location in Illinois. It is hoped then to apply systems analyses, including economic factors, to bring coal and water together in the most effective way.

6.9.15

PROCEEDINGS OF THE WORKSHOP ON RESEARCH NEEDS RELATED TO WATER FOR ENERGY HELD IN INDIANAPOLIS, INDIANA ON OCTOBER 20-22 1974

Illinois Univ., Urbana. Water Resources Center. Office of Water Research and Technology, Washington, DC

Research Report

Stout, G.E.

Nov 74 299p

Report No. UILU-WRC-74-0093

Contract: DI-14-31-0001-4271

Project: OWRT-X-147(4271)

Monitor: OWRT-X-147(4271)(1)

Abstract: Development of large scale energy conversion facilities and their impact on water resources in the Ohio River, Great Lakes and Upper Mississippi River basins was studied at an interdisciplinary workshop. Within limits determined by available water resources and minimization of environmental impact, participants identified areas in which research will be needed if energy conversion facilities are developed. Coal gasification and liquefaction received special emphasis. Included are 2 papers on coal conversion processes and related water requirements, 9 papers with commentaries related to main topic and reports of discussion groups which identify research needs and rank them in importance.

NTIS PB-241 346/6ST

6.9.16

H₂O: THE LIMITING REACTANT IN THE ENERGY EQUATION

Manahan, S.E.

University of Missouri, Columbia

Am. Chem. Soc., Div. Environ. Chem., Prepr. 15/1/1975

198-200

169, ACS National Meeting

Philadelphia, PA

6 Apr 1975

Abstract: According to a study supported by the U.S. Department of the Interior, water is the key component of any energy system. Domestic energy self-sufficiency can only be attained by the use of coal in the intermediate term of 30 to 50 years. The increased reliance on coal will strain available water supplies. 30 to 40 percent of the original heat content of coal is lost during the conversion to liquid or gaseous fuels. The primary coal-derived synthetic fuels will be SNG, sulfur-free low-Btu gas, solvent refined coal, low-sulfur liquid boiler fuels, and liquid hydrocarbon fuels including, gasoline, diesel fuel, and naphtha and 100 SNG plants, each producing 250 million cu.ft./day SNG, would supply only 5 percent of the projected U.S. energy demand in 2000 (based on historical growth rates). The water requirements for each plant of this capacity will total 19,600 to 48,900 acre ft/yr depending on the quantity of makeup cooling water required.

6.9.17

SULFUR AND NITROGEN BALANCES IN THE SOLVENT REFINED COAL PROCESS

Pittsburg and Midway Coal Mining Co., Merriam, Kansas, National Environmental Research Center, Research Triangle Park, N.C., Control Systems Lab.*Office of Coal Research, Washington, DC

Environmental protection technology series (final)

Wright, Charles H.

Jan 75 150p

Contract: DI-14-01-0001-496

Project: EPA-ROAP-21ADD-025

Monitor: EPA/650/2-75/011

Prepared in cooperation with Office of Coal Research, Washington, DC

Abstract: The report gives results of an exact elemental balance study of the Solvent Refined Coal (SRC) process that was conducted with the laboratory reactor to determine the fate of sulfur and nitrogen in the SRC process. The work was performed in late 1972 as part of a normal experiment with Kentucky No. 9 high volatile B bituminous coal and a blend of processed anthracene oils under 1000 psig hydrogen

(cont'd.)

pressure. A variety of technique studies had been made in preparation such as investigation of the effects of sample size on analysis and methods of handling all samples of input and output material for maximum recovery and representative composition. Accounting for carbon and hydrogen was accurate, for sulfur good, and for nitrogen poor. A detailed comparison of conventional Kjeldahl and Dumas analytical results for nitrogen in coal and solid products revealed that input nitrogen is not fully reported by Kjeldahl and that sample size affects nitrogen results reported by Dumas. Nitrogen analysis needs further investigation. The study forced review of sampling and handling techniques as well, with salutary results in laboratory work.

NTIS PB-243 893/5ST

6.9.18

ENVIRONMENTAL IMPACTS, EFFICIENCY, AND COST OF ENERGY SUPPLY AND END USE. VOLUME II

Hittman Associates, Inc., Columbia, MD, National Science Foundation, Washington, DC Environmental Protection Agency, Washington, DC, Council on Environmental Quality, Washington, DC (387 333)

Final Report

Jan 75 271p

Report No: HIT-593

Contract: EQC-308

Monitor: EQC-308v2

Prepared in cooperation with National Science Foundation, Washington, DC. See also Volume 1, PB-238 784.

Abstract: This volume focuses on six emerging energy technologies as components of future energy supply trajectories. Five of the six technologies - low Btu gasification, high Btu gasification, fluidized bed boiler combustion, solvent refined coal, and coal liquefaction - use coal in the production of synthetic fuels or electricity. The sixth, oil shale technology, considers the production of crude oil from this new energy source. For those technologies using coal, the environmental impacts, efficiencies, and costs are developed for three regional coals and a national average case. The coals for which data are developed include a low sulfur (Northwest), medium sulfur (Northern Appalachia), and high sulfur (Central) coal.

NTIS PB-239 159/7ST

6.9.19

PROCESS SYSTEMS FOR CONVERSION OF DIFFICULT FUELS TO SYNTHETIC FUELS
FOR BASELOAD GAS TURBINES

Ahner, D.J., Booth, W.A.
GE, Schenectady, NY
2-6 1975 8p

Abstract: Rapid changes in the fuel availability and cost picture, coupled with environmental concerns, emphasize the need to consider new concepts for power generation by industrial plants and electric utilities. A number of processes are now being developed to produce clean gaseous and liquid fuels from coal and low-grade petroleum products which offer potential for use in gas turbine-based power generating systems. This paper reviews several of the processes and considers the economic and environmental factors affecting their application to power generation systems. 12 refs.

6.9.20

EVALUATION OF POLLUTION CONTROL IN FOSSIL FUEL CONVERSION PROCESSES.
LIQUEFACTION: SECTION 2. SRC PROCESS

Exxon Research and Engineering Co., Linder, NJ, National Environmental
Research Center, Research Triangle Park, NC Control Systems Lab.

Final Report
Jahnig, C.E.
Mar 75 88p
Report No. GRU.8DJ.75
Contract: EPA-02-0629
Project: EPA-ROAP-21ADD-023
Monitor: EPA/650/2-74-009-f
See also PB-241 141.

Abstract: The report gives results of a review of the Solvent Refined Coal (SRC) process from the standpoint of its potential for affecting the environment. It includes estimates of the quantities of solid, liquid, and gaseous effluents, where possible, as well as the thermal efficiency of the process. It proposes a number of possible process modifications or alternatives which could facilitate pollution control or increase thermal efficiency, and points out new technology needs.

NTIS PB-241 792/1ST

6.9.21

POTENTIALLY HAZARDOUS EMISSIONS FROM THE EXTRACTION AND PROCESSING
OF COAL AND OIL

Battelle Columbus Labs., Ohio, National Environmental Research Center,
Research Triangle Park, NC, Control Systems Lab (407 080)

Final Report

Lebowitz, H.E., Tam, S.S., Smithson, G.R., Jr., Nack, H., Oxley, J.H.

Apr 75 162p

Contract: EPA-68-02-1323

Project: EPA-ROAP-21AFH-025

Monitor: EPA/650/2-75-038

Abstract: The report lists potentially hazardous materials which may be associated with the air, water, and solid waste from a refinery, a coke plant, a Lurgi high-Btu gas process, and the solvent refined coal process. Fugitive loss was identified as the major emissions source in the refinery, although its composition is difficult to quantify. Coking is the most offensive of the four processes assessed. Coal gasification may produce materials as dangerous as those from the coke plant, but the former will probably be more contained than coke oven emissions. The environmental impact of coal liquefaction is not well defined; however, liquefaction products will probably be more hazardous than crude oil products, and their refining and utilization will be worse offenders than corresponding petroleum operations.

NTIS PB-241 803/6ST

6.9.22

ENVIRONMENTAL EFFECTS, IMPACTS AND ISSUES RELATED TO LARGE SCALE COAL REFINING
COMPLEXES. PERIOD COVERED, AUGUST 1974--DECEMBER 1974

Hittman Associates, Inc., Columbia, Md.

May 75 87p

Rept. No. OCB-101-INT-2

Abstract: The study covers the development and analysis of strategies for siting, building, and operating coal conversion industrial complexes with respect to environmental protection. Coal refinery complexes with capacities to product up to 10^9 cu ft of pipeline gas and up to 40,000 tons per day of solid and liquid products are used to characterize the scope of the operations. Five major coal-bearing regions of the country having coal reserves and concentrations capable of supplying coal in the required quantities are identified: Appalachia; Eastern Interior; Fort Union; Powder River, and Four Corners. Conjunctive support facilities including new support industry development, are characterized in terms of residuals, disturbances, and environmental control approaches and strategies. Impacts that cannot be completely mitigated, the relationship of long-term productivity and short-term use, and the identification of irreversible and irretrievable resource commitments are discussed.

6.9.23

EVALUATION OF R AND D INVESTMENT ALTERNATIVES FOR SO_x AIR POLLUTION
CONTROL PROCESSES, PART 2

Kellogg (M.W) Co., Houston, Tex., Industrial Environmental Research Lab,
Research Triangle Park, NC

Final report Mar-Dec 74

Caceres, S., Do, L., Gonzalez, N., Kahn, H.A., Mathur, G.K.

Aug 75 270p

Contract: EPA-68-02-1308

Project: EPA-ROAP-21ADE-010

Monitor: EPA/650/2-74/098a

See also report dated Sep 74, PB-238 263.

Abstract: The report gives results of an extension of work done in Part 1 of the study, reported in September 1974. Of the five major sources of sulfur oxide emissions studied in Part 1, new or enlarged data bases are presented for three: utility plants, industrial boilers, and sulfuric acid plants, cost models developed for the wet limestone process and the Wellman/Allied process are applied to these source groups, and the results summarized. Application of the Wellman/Allied system to Claus plants is also discussed. Economics are shown for a "packaged" limestone scrubbing system for small industrial boilers. Cost models, derived from the model for substitute natural gas plants developed in Part 1, are included for low-Btu and intermediate-Btu gas plants. Production costs of substitute natural gas, low-Btu gas, and solvent refined coal are presented, based on actual coal prices in the U.S.

NTIS PB-250 724/2ST

6.9.24

SOCIAL, ECONOMIC AND ENVIRONMENTAL IMPACTS OF COAL GASIFICATION AND
LIQUEFACTION PLANTS

Broderson, A.B., Edwards, R.G., Hauser, W.P.

AME Technol, Inc., Lexington, Ky

Source-Coal Util Symp, 2nd, at Natl Coal Assoc/Bitum Coal 70-89.

Sponsored by NCA, Washington, DC 1975

Abstract: This paper is the result of an 8-month study funded by the Institute of Mining and Minerals research of the University of Kentucky. During this study written correspondence was evaluated from 78 companies or agencies queried, one gasification and one liquefaction pilot plant were toured, and 360 other references were reviewed, including Environmental Impact Statements for 8 proposed coal conversion plants. A full report has been submitted. The paper attempts to summarize the findings, and present the impacts of a "typical" coal conversion plant. 2 refs.

6.9.25

SITING ENERGY FACILITIES AT GLASGOW AIR FORCE BASE. VOLUME III

Montana Energy and MHB Research and Development Inst., Inc., Butte,
Federal Energy Administration, Washington, DC, Office of Energy
Resource Development

Nov 75 156

Contract: FEA-CO-05-50114-00

Monitor: FEA/G-75/421

Abstract: The feasibility of establishing an energy center at Glasgow Air Force Base, near Glasgow, Montana is studied. Volume III presents a discussion and analysis of the environmental effects of coal conversion and energy facilities siting, including socio-economic impact projections for a conceptual energy center at Glasgow AFB.

NTIS PB-252 712/5ST

6.9.26

ORGANIC CONSTITUENTS IN PROCESS STREAMS OF A SOLVENT-REFINING COAL PLANT. PROGRESS REPORT

Battelle Pacific Northwest Labs., Richland, Wash., Energy Research
and Development Administration (9500022)

Petersen, M.R.

Dec 75 10p

Contract: E(45-1)-1830

Monitor: 18

Abstract: The most important observation is that the same major organic components are present in all the samples investigated: process "naphtha", process solvent, extracts of solvent-refined coal, mineral residue and effluent water. However, the distribution of the organic compounds changes with the type of sample. The compounds which have been identified are not necessarily those eventually escaping into the environment. This initial investigation consisted of looking at the process streams to determine potential pollutants and develop techniques for isolating the organic constituents. The next step is to sample actual effluents coming from the plant. These include the process water after treatment, the gaseous emissions and any particulates. P and M is aware of the potential carcinogenic nature of the various process streams and have taken steps to insure that plant personnel are protected and that sound industrial hygiene practices are followed. Many of the compounds which have been identified are toxic, especially the phenols and quinolines. The plant design criteria should result in very low concentrations of organic compounds, mainly phenols, in the liquid effluent and our analysis of effluent water from the biological digester will show the actual concentrations. We have identified only one reported carcinogenic compound

(cont'd.)

(dibenzothiophene) thus far. However, we are developing techniques to analyze for other minor constituents of concern including benzo (a) pyrene, a known carcinogen. The organic compounds identified in the samples from the solvent-refined coal plant at Fort Lewis, Washington, are listed.

NTIS BNWL-B-470

6.9.27

SYNTHETIC FUELS COMMERCIALIZATION PROGRAM, IV, DRAFT ENVIRONMENTAL IMPACT STATEMENT

Energy Research and Development Administration, Washington, DC
DEC 1975
ERDA--1574(Draft)

Abstract: A draft environmental impact statement has been prepared for a synthetic fuels program to provide the equivalent of 350,000 barrels of oil per day initially, and possibly 1,000,000 barrels per day by 1985. A variety of incentives is recommended to facilitate the accomplishment of the program. Various coal gasification and liquefaction processes, oil shale processes and a solid waste pyrolysis process are described briefly. Several coal and oil shale regions with sufficient reserves are described and a tentative choice of plant type is made for each. Environmental effects are treated: air pollution (sulfur oxides, nitrogen oxides, particulates, hydrocarbons, carbon monoxide, aldehydes, and probably some possibly carcinogenic polycyclic aromatic hydrocarbons). Water quality degradation (including considerable water requirements, aquifer and stream disruption, erosion, sedimentation, acid mine drainage, various pollutants). Terrain changes due to mining, construction, solid waste disposal (spoil banks). Effects on flora, fauna, agriculture and effects on municipalities. Several alternative courses of action are treated briefly. (LTN)

6.9.28

ENVIRONMENTAL IMPACT OF COAL RESEARCH AND DEVELOPMENT. MONTHLY PROGRESS REPORTS, FEBRUARY 1--MAY 31, 1975

Hittman Associates, Inc., Columbia, MD (3005000)

1975 340p
Monitor: 18

Abstract: A survey of U.S. energy needs for the next 50 years leads to the conclusion that a much greater use of coal is inevitable, although the exact amount of coal needed annually is not predicted accurately due to uncertainties in progress on other programs. Use of coal in large, complex plants (electric power, coal gasification, coal liquefaction) using a total of approximately 100,000 tons of coal per day

(cont'd.)

(depending on quality) is visualized. There are only a few areas in the U.S. with sufficient coal, land, and water resources for the estimated required life of such complexes (30 years). The candidate technologies for such a plant are reviewed. Unless a methanation process is added to most gasification processes to produce high-Btu substitute natural gas, the product is a low-Btu gas and must be used locally. The methanation process is exothermic and requires catalysts (which are sensitive to sulfur) and is difficult to control (but liquid phase and fluidized-bed methanation are under development and may be more susceptible to control and also heat recovery). Many engineering problems exist (refractories, alloys to withstand corrosion, catalysts (sulfur-resistant), pressurized feeding systems, heat transfer, heat recovery (to improve efficiency), removal of tars, char, ash, etc., destruction of caking, shift process, sulfur removal and recovery, waste water treatment, etc.). More briefly, coal liquefaction (solvent refined coal, COED process), fluidized-bed combustion (with limestone or dolomite to retain the SO_2) MHD generators, in-situ gasification, and continued gas turbine steam cycles are reviewed.

NTIS FE-1508-T-5

6.9.29

SOME COST, ENERGY, ENVIRONMENTAL, AND RESOURCE IMPLICATIONS OF SYNTHETIC FUELS PRODUCED FROM COAL FOR MILITARY AIRCRAFT

Rand Corp, Santa Monica, California

Stanley, W.L.

Source- Rand Corp Paper P-5578 Feb 1976 22p

Abstract: The findings suggest that coal and oil shale are the most promising energy resource alternatives. A synthetic jet fuel similar to jet fuels in use today appears to be the most attractive aviation fuel derivable from coal, primarily because its production requires lower energy expenditures and results in a less costly fuel product than any other two major alternatives, liquid hydrogen and liquid methane, while offering attractive characteristics for aviation applications. Despite its attractive features, there are definite resource capacity, and environmental constraints which could tend to limit the availability of synthetic jet fuels in the future. 26 refs.

6.9.30

IMPACT OF CLEAN FUELS COMBUSTION ON PRIMARY PARTICULATE EMISSIONS
FROM STATIONARY SOURCES

Acurex Corp., Mountain View, Calif. Aerotherm Div., Industrial
Environmental Research Lab., Research Triangle Park, NC (407 435)

Final report Mar-Sep 75

Ferrell, J., Poe, G.

Mar 76 81p

Report No: Aerotherm-FR-75-175

Contract: EPA-68-02-1318

Project: EPA-ROAP-21ADK-004

Monitor: EPA/600/2-76/052

Abstract: The report gives results of an examination of various coal conversion processes proposed for sulfur removal, to determine the implications for particulate removal requirements when the converted fuels are burned. A substantial increase in the near future is foreseen for the use of high-sulfur coal for large scale steam raising. A major reduction in SO_2 emissions from those sources will be required to meet state and federal standards, either by desulfurizing the fuel or by removing SO_2 from the flue gas. Limited information is available on the combustion of synthetic fuels but, based on the data obtained and the nature of the fuels, little problem is foreseen in meeting effluent requirements for particulates. Other factors upstream of the combustion of those fuels (e.g., turbine blade erosion or methanation catalyst poisoning) seem more likely to determine particulate removal requirements. The costs of sulfur removal by flue gas desulfurization (FGD) were examined briefly. The cost savings potentially obtained by elimination of effluent particulate control systems with synthetic fuels were insignificant in affecting the substantial cost advantage of FGS versus fuel conversion.

NTIS PB-253 452/7ST

6.9.31

EVALUATION OF POLLUTION CONTROL IN FOSSIL FUEL CONVERSION PROCESSES

Exxon Research and Engineering Co., Linden, NJ, Industrial Environmental
Research Lab., Research Triangle Park, NC

Final Report Jun 72-Jan 76

Magee, E.M.

Apr 76 306p

Report No: EXXON/GRU.16DJ.76

Contract: EPA-68-02-0629

Project: EPA-ROAP-21ADD-023

Monitor: EPA/600/2-76/101

See also PB-249 845

Abstract: The review gives an overview of work, between June 1972 and January 1976, on various environmental aspects of fossil fuels. Details

(cont'd.)

of this work is presented in 14 reports published during this same period. The details include potential pollutants in fossil fuels; quantities of solid, liquid, and gaseous effluents from coal treatment and conversion to gaseous and liquid fuels; and an analytical test plan for coal conversion systems. The overview report discusses commonality and differences in the reviewed processes with emphasis on factors which might effect the environment when the processes are in commercial use. Due to the lack of a sufficient data base, data and research and development needs are also addressed.

NTIS PB-255 842/7ST

6.9.32

SOCIAL, ECONOMIC, AND ENVIRONMENTAL IMPACTS OF COAL GASIFICATION AND LIQUEFACTION PLANTS

Kentucky Univ., Lexington Inst. for Mining and Minerals Research, AME Technology, Inc., Lexington, Ky., Watkins and Associates, Inc., Lexington, Ky.

Final Report

Edwards, B. G., Broderson, A. B., Hauser, W. P.

Apr 76 270 p

Rept. No. IMMR14-GR2-76

Prepared in cooperation with AME Technology, Inc., Lexington, Ky. and Watkins and Associates, Inc., Lexington, Ky.

Abstract: Adverse impacts of coal conversion are discussed including air, water, noise, and solid waste pollution. Also covered are occupational health and safety, land use and reclamation, and impact on the lifestyle of rural area residents.

NTIS PB-252 747/CST

6.9.33

SPHALERITE IN COALS FROM THE ILLINOIS BASIS

U.S. Geological Survey, Denver, Colorado

Hatch, J.R., Gluskoter, H.J., Lindahl, P.C.

Source - Econ Geol v 71 n 3 May 1976 p613-624

Abstract: Chemical analyses of 81 samples of coal from the Illinois Basin suggested the occurrences, in many instances, of a separate zinc sulfide phase. Field investigations proved this, and a number of sphalerite samples were collected for study from coals in northeastern, southeastern, and northwestern Illinois. The highest concentration of sphalerite in Illinois coals is in northwestern Illinois where sphalerite is present in all three of the coals mined. The sphalerite is generally cadmium rich: ratios of zinc to cadmium in the sphalerite samples extracted from coals range from 48/1 to 358/1. The Zn/Cd for sphalerite samples from Illinois and Kentucky that were collected from strata other than coal range from 29/1 to 1020/1. Sphalerite occurs in coal principally as fillings in cleats (vertical fractures). Pyrite, quartz, kaolinite, and calcite are associated with the sphalerite. The paragenetic sequence began with a sulfide stage, continued with a silicate stage, and concluded with a carbonate stage. The sphalerite is epigenetic and was deposited slowly under conditions near equilibrium. The cleats provided channels in the coal along which the mineralizing solutions could move, and the coal in turn provided a suitable substrate for the bacterial reduction of sulfate to sulfide and/or a source of reduced sulfur. The sphalerite is readily removed from the coal by washing (separation by specific gravity techniques) and can be recovered. A zinc content as high as 5350 ppm and cadmium content as high as 65 ppm, both on a whole coal basis, were observed. The economic recovery of these elements should be considered, especially when coal conversion processes are being planned. Refs.

6.9.34

ENVIRONMENTAL ASPECTS OF THE SRC PROCESS

Pittsburg and Midway Coal Mining Co., Research Triangle Inst.,
Research Triangle Park, NC

Perrussel, R.E., Hubis, W., Reavis, J.L.

8 Refs

June 1976

Symposium Proceedings: Environmental Aspects of Fuel Conversion
Technology, II, Ayer, F.A. (Comp)

Hollywood, Florida

15 Dec 1975

Abstract: The prime purpose of the solvent refined coal (SRC) process is to produce a clean, low-ash, low-sulfur solid fuel from high-ash and/or high-sulfur coals of various ranks for use in stationary combustion systems. This paper presents an overview of the SRC process and its associated environmental problems. Some of the topics discussed are: The process description, plant site, baseline and proposed environmental studies, fugitive particulates and vapors, process waste disposal system, tract elements programs and sulfur plant. SRC pollution problems are similar to those faced by other industries and can be handled adequately with existing technology to meet environmental standards.

6.9.35

SYMPOSIUM PROCEEDINGS: ENVIRONMENTAL ASPECTS OF FUEL CONVERSION
TECHNOLOGY, II (DECEMBER 1975, HOLLYWOOD, FLORIDA)

Research Triangle Inst., Research Triangle Park, NC, Industrial
Environmental Research Lab., Research Triangle Park, NC (304 400)

Final Report

Ayer, Franklin A.

Jun 76 389p

Contract: EPA-68-02-1325

Monitor: EPA/600/2-76/149

See also PB-238 304.

Abstract: The report covers EPA's second symposium on the environmental aspects of fuel conversion technology. The symposium was conducted at the Diplomat Hotel, Hollywood, Florida, December 15-18, 1975. Its main objective was to review and discuss environmentally related information in the field of fuel conversion technology. Specific topics were environmental problem definition, process technology, control technology, and process measurements.

NTIS PB-257 182/6ST

6.9.36

ORGANIC CONTAMINANTS IN AQUEOUS COAL CONVERSION EFFLUENTS: ENVIRONMENTAL CONSEQUENCES AND RESEARCH PRIORITIES

Oak Ridge National Lab., Tenn., Energy Research and Development Admin.
Herbes, S. E., Southworth, G. R., Gehrs, C. W.
1976 20 p
10th Annual conference on trace substances in environmental health,
Columbis, Missouri, USA, 8 June 1976

Abstract: The anticipated implementation of an extensive coal conversion industry in the United States within several decades will result in production of substantial quantities of highly contaminated wastewater. Many of the contaminants produced, if released into natural waters, could have deleterious effects on aquatic ecosystems, and ultimately, on human life. Research is required to determine potential acute and sub-acute effects of potentially hazardous effluents constituents, and to evaluate their transport and persistence in aquatic systems. To facilitate a rational assignment of future aquatic research priorities to answer these issues, we have initiated a systematic assessment of the environmental hazards of anticipated organic components of aqueous coal liquefaction effluents by the compilation of a critical literature review. Five major classes of organic compounds have been operationally defined: (1) Phenols; (2) polycyclic aromatic hydrocarbons (PAH); and (5) sulfur-containing compounds. A summary assessment of each class is presented on the basis of (1) concentrations anticipated in coal liquefaction effluents; (2) removal by wastewater treatment systems; (3) acute toxicity; (4) chronic toxic effects on aquatic organisms; and (5) environmental transport and persistence. Gaps in understanding and future research needs are identified.

NTIS CONF-760632

6.9.37

DETERMINING EMISSIONS MEASUREMENTS NEEDS FOR AN EMERGING INDUSTRY-ADVANCED FOSSIL FUELS UTILIZATION

Oak Ridge National Lab., Tenn., Energy Research and Development Admin.
Guerin, M. R., Epler, J. I.
17 June 1976 30p
Symposium - determining fugitive emissions measurements needs, Hartford, Colorado, USA, 17 May 1976

Abstract: The existence of extent of environmental and health problems related to coal gasification or liquefaction plants cannot be determined at present because commercial scale plants do not exist. Few processes have yet reached the demonstration plant scale. Methods are required, however, to quickly and reliably assess the extent of the problem as large scale operations are initiated. Data generated in the course of methods development may also be useful in designing control technologies.

(Cont'd)

One approach to establishing reliable methods and generating data of value in setting priorities on environmental and health studies is presented. Measurements needs are identified through an experimental assessment of existing methods. The number of combinations of processes, sample types, and chemicals available for study is staggering. Bioassay data (when health effects are of interest) and environmental data (when environmental impact is of interest) provide a rational basis for determining research priorities. If carcinogenesis is of interest, results of the Ames test are accepted as indicators of carcinogenesis, and the additivity of mutagenic activities of chemical fractions are accepted, bioassay results reported here suggest that the neutral and ether-soluble basic attention. The assumptions leading to this conclusion and the bioassay methodologies require considerable basic research for validation but any guidance at this point is invaluable. Studies carried out now must emphasize methods development in preparation for process evaluation. Measurements research needs are identified and listed based on referenced work and work reported here.

NTIS CONF-760563-1

6.9.38

CHARACTERIZATION OF INORGANIC POLLUTANTS: MATCHING MEASUREMENTS TO QUESTIONS

Natusch, D.F.S.

Colorado State University, Fort Collins

Sampling Strategy and Charact of Potential Emiss from Synfuel Prod. Symp/Workshop, Proc. Austin, Tex. June 8-10 1976

Publ by ERDA (CONF-760602), Washington, DC 1976.

Available from NTIS, Springfield, Va p 82-112

Abstract: This paper presents a discussion of the physical and chemical characteristics of inorganic pollutants derived from the so-called synfuel and related processes insofar as these characteristics influence the environmental impact of such processes. Two distinct approaches are considered. The engineering approach generally involves collection of a considerable number of samples under conditions such that they are closely representative of different points in several pollutant streams within a given plant. A rather small number of essentially straightforward physical (e.g., temperature, flow rate, particle mass) and chemical (e.g., elemental analysis, inorganic gas analysis) measurements are then performed on each sample. The results establish the identify and amounts of prespecified pollutants and are used primarily for calculating emission rates and mass
(Cont'd)

balance data. The chemical approach to characterization all too frequently involves investigation of a limited number of samples which may or may not be representative of the system being studied. These samples are subjected to a number of primarily non-routine analyses and specifically designed experiments to elucidate the fundamental factors which determine the formation, transformation, distribution, and physico-chemical behavior of each pollutant. The results obtained frequently provide a detailed understanding of the actual physical and chemical processes which are operating and, as such, are generally applicable to different plants. Details of both approaches are given. Extensive analytical data are tabulated, plotted and evaluated in terms of inorganic pollutants characterization. 32 refs.

6.9.39

SAMPLING STRATEGY AND CHARACTERIZATION OF POTENTIAL EMISSIONS FROM
SYNFUEL PRODUCTION -- SYMPOSIUM/WORKSHOP -- PROCEEDINGS, 1976

Anon

ERDA, Washington, DC

Sampling Strategy and Charact of Potential Emiss from Synfuel Prod, Symp/
Workshop, Proc. Austin, Tex. June 8-10 1976

Publ by ERDA (CONF-760602), Washington, DC 1976.

Available from NTIS, Springfield, Va

146 p

Abstract: This volume contains lectures and structured workshops dealing with the production of synthetic fuels from coal and oil shale as it affects sampling and analysis of potential emissions during coal liquefaction, coal gasification and oil shale retorting. Among others, a review is given of coal liquefaction research work in the United States and of oil shale processing technology above ground and below. Most lectures were concerned with environmental impact of coal conversion technology and relevant control of air and water pollution. Some papers are abstracted and indexed separately.

6.9.41

CHARACTERIZATION OF ORGANIC POLLUTANTS: MATRICES AND MEASUREMENTS

Rosebrook, Donald D.

Radian Corp., Austin, Tex.

Sampling Strategy and Charact of Potential Emiss from Synfuel Prod. Symp/ Workshop, Proc, Austin, Tex. June 8-10 1976

Publ by ERDA (CONF-760602), Washington, DC, 1976.

Available from NTIS, Springfield, Va p 65-77

Abstract: This paper is concerned with sampling and characterization of processing streams in plants converting coal into liquid fuels with particular emphasis on organic chemicals polluting environment. The samples which may be presented to the laboratory are: solid (particulates, residues, suspended solids), aqueous liquid (homogeneous, heterogeneous) organic liquid, free gas, and sorbed vapors. The samples may be in a solid matrix such as particulates from stack sampling, residues such as char or ash from the gasifier itself, or suspended solids in the liquid effluent. The aqueous liquid samples may be effluent from various parts of the processes and they may be either homogeneous liquids or heterogeneous liquids. Separation procedures, as well as instrumental analysis used for pollutant characterization are discussed in some detail. Types of pollutants which may be present in process streams are listed.

6.9.42

CHARACTERIZATION REQUIREMENTS FOR EARLY AND SAFE IMPLEMENTATION OF FOSSIL FUEL TECHNOLOGY

Cowser, Kenneth E.; Liverman, James L.

ERDA, Washington, DC

Sampling Strategy and Charact of Potential Emiss from Synfuel Prod., Symp/ Workshop, Proc. Austin, Tex. June 8-10 1976

Publ by ERDA(CONF-760602), Washington, D.C. 1976

Available from NTIS, Springfield, Va p 2-5

Abstract: This paper discusses in general terms the problem of environmental protection connected with the future industry of coal conversion and oil shale processing aimed at the mass production of synthetic fuels. It is demonstrated that the production of sufficient synthetic fossil fuels in a safe and environmentally acceptable manner will require the coordinated efforts of government agencies, private industry and particularly of knowledgeable and dedicated engineers and scientists. To achieve this goal sound recommendations must be formulated for the sampling and characterization technology which are essential for establishing operating guidelines for a safe and environmentally acceptable synthetic fossil fuel industry.

6.9.43

LEGAL INSTITUTIONS FOR THE ALLOCATION OF WATER AND THEIR IMPACT ON
COAL CONVERSION OPERATIONS IN KENTUCKY

Kentucky Water Resources Research Inst., Lexington, Office of Water
Research and Technology, Washington, DC

Research Report

Ausness, R.C., Callahan, G. W., Dills, S.W., Flynn, W.H., Gillig, J.S.
Aug 76 196p

Report No: RR-95

Contract: DI-14-31-0001-5017, DI-14-34-0001-6018

Project: OWRT-A-060-KY

Monitor: OWRT-A-060-KY(2)

Abstract: Coal conversion plants require large quantities of water for cooling purposes and for use as a raw material. Three types of water allocation are presently used in the United States: riparianism, prior appropriation, and administrative permit systems. Kentucky presently has such a system of administrative allocation and this is described in the report.

NTIS PB-256 796/4ST

6.9.44

CHARACTERIZATION OF SUBSTANCES IN PRODUCTS, EFFLUENTS AND WASTES FROM
SYNTHETIC FUEL PRODUCTION TESTS, QUARTERLY PROGRESS REPORT

Battelle Pacific Northwest Labs., Richland, Washington

Petersen, M.R., Fruchter, J.S., Lall, J.C.

Contract: EY-76-C-06-1830

Sep 1976

BNWL-2131

Abstract: Battelle-Northwest is working under contract with the Energy Research and Development Administration to characterize materials from promising synthetic fossil fuels. The objectives of this work are to determine what materials may possibly enter the environment as a result of the full-scale commercial operation of such processes which may be detrimental from an environmental or health standpoint. The early characterization of such materials would permit ample time for appropriate control techniques to be implemented prior to full-scale commercialization. These quarterly reports are intended to provide up-to-date information on the status of these characterization efforts, both to those concerned with techniques and abatement process development and to the biological and environmental scientists working in this area.

6.9.45

ROLE OF ENVIRONMENTAL DATA BANKS IN ENERGY RESOURCE DEVELOPMENT

University of Kentucky, Lexington

Jones, J.E., Smith, G.E.

Source - Int Conf on Environ Sensing and Seese, Jt Conf Comprising the Int Symp on Environ Monit and the 3rd Jt Conf on Sensing Environ Pollut, Las Vegas, Nev, Sep 14-19 1976 Publ by IEEE (Cat n 75-CH 1004-1 ICESA), New York, NY 1976 v 2 Pap 25-6, 5 p

Abstract: The paper describes the rationale for the implementation of an Environmental Data, Information and Literature Bank being developed. The bank's major emphasis concerns the environmental, social, and economic aspects of producing clean solid, liquid and gaseous fuels from coal. The data bank promotes information interchange between other related governmental and private projects and the energy development community. The general need for the operation of environmental data banks in support of energy development is discussed. An overview of coal conversion (the potential magnitude of the industry, the environmental considerations, and the general types of informational resources of environmental assessment) is presented. 13 refs.

6.9.46

ENVIRONMENTAL STUDIES OF TWO PROCESSES FOR SYNTHETIC FUELS FROM COAL

May, V. Bruce, Dykstra, Kewey I.; Emerson, Dwight B.; Goldschmid, Tanhum Hittman Assoc., Inc., Columbia, Md.

Symp on Coal Util, 3rd, NCA/BCR (Nat'l Coal Assoc/Bitum Coal Res. Inc) Coal Res. Inc) Coal Conf and Expo 3, Pap, Louisville, Ky, Oct 19-21 1976 Publ by NCA, Washington, DC, 1976 p 121-140

Abstract: Coal is unique in that, while it is the most abundant fuel in the United States, its uncontrolled use is environmentally unacceptable by current standards. Technology is under development to permit coal to be utilized as a clean fuel in competition with such premium energy sources as natural gas and petroleum products. Two processes, the Synthane high-Btu gasification process and a modification of the Solvent Refined Coal (SRC) process, are considered in this discussion from an environmental point of view. The Synthane process produces substitute natural gas, while the modified SRC process yields a mix which is primarily liquid fuels but includes gaseous and solid products. Environmental problems are discussed which are encountered at each stage of coal liquefaction or coal gasification plants. Recommendations are included. Refs.

6.9.47

HIGH PRECISION TRACE ELEMENT AND ORGANIC CONSTITUENT ANALYSIS OF OIL SHALE AND SOLVENT-REFINED COAL MATERIALS

Fruchter, J. S.; Laul, J. C.; Petersen, M.R.; Ryan, P. W.
Battelle - Northwest, Richland, Wash.

Am Chem Soc Div Pet Chem Prepr v 22 n 2 March 1977; Anal Chem
of Tar Sands and Oil Shale, New Orleans, La. Mar 20-25 1977 p 793-807

Abstract: The application of a number of sensitive and precise methods for the determination of trace elements, heavy element species, and organic compounds in materials from one oil shale research retort process and from a solvent-refined coal plant operation are discussed. The methods used were chosen both for their sensitivity and their relative freedom from interferences. Although only a limited number of samples have been analyzed so far, certain conclusions can be drawn from the data.

(1) Broad spectrum inorganic and organic analytical techniques provide the best approach for the initial characterization of the complex samples encountered in working with new energy technologies such as oil shale retorting and solvent refining of coal. (2) The techniques used must be capable of good precision so that analytical errors will not add to other errors in difficult sampling situations and so that the true magnitude of differences caused by process and feedstock variables can be measured.

10 refs.

6.9.48

WATER CONSERVATION AND POLLUTION CONTROL IN COAL CONVERSION PROCESSES

Goldstein, D. J. and Yung, David

Water Purification Associates, Cambridge, Mass. Jun 77.

486p EPA/600/7-77-065

Abstract: The report gives results of a study to determine water consumption and environmental impacts of coal conversion processes in Western states. Part 1 gives brief descriptions and process water requirements for nine conversion processes. Detailed designs and analyses are given for the Hygas, Synthane, and Solvent Refined Coal (SRC) processes, and for Lurgi combined-cycle power generation. At three proposed sites (in North Dakota, New Mexico and Wyoming), complete water requirements and effluents, including all mining and related off-site uses, are given for the power, Hygas, and SRC plants. The Wyntane process is analyzed only at the Wyoming site. Part 2 gives analyses of influent and effluent waters, with examples for study. For the three selected plants at the North Dakota site, source water of good quality is assumed to be cheap and available. For three plants in New Mexico, source water will be available but is brackish. All the plants at the Wyoming site receive sewage from a satellite town; additional fresh water is available but is assumed to be expensive. For each process at each site (10 cases) an integrated water treatment plant block flow diagram is given with approximate costs and energy requirements.

PB-269 568/2WP

6.10 COAL PROCESSING ECONOMICS

Papers included in this section cover primarily the preliminary economics of commercial size SRC plants. These include studies published by Pittsburgh and Midway, Ralph M. Parsons, Dravo, and U.S. Bureau of Mines and others. Some papers compare the economics of SRC as a utility fuel with flue gas desulfurization and coal gasification. Several articles describe economic and cost models for SRC process and the energy coefficients developed. Papers on the economics of COG refinery concept as well as H-coal process are also included because of many similarities in developing the cost pictures. Papers on coal derived chemicals are also included as are those describing economic projections.

6.10.1

THE POSSIBILITIES OF SOLVENT REFINED COAL

George Washington University, Washington, D. C.
School of Engineering and Applied Science. (153-370)
Jameson, Robert M.
22 Feb 65 142p

Abstract: The broader utilization of coal is often hampered by coal's physical properties and its high ash and sulfur content. Coal's physical properties can be favorably altered and its high ash and sulfur content greatly reduced by solvent refining. The thesis describes a process for solvent refining of coal and applies a production cost formula to estimate the selling price of refined coal in various sections of the world. Utilizing these prices as a base the potential size of the competitive market available to solvent refined coal is estimated up to the year 1980. Sizeable economically competitive markets became apparent in the combustion, metallurgical, and diesel propulsion fields. These markets are estimated at a total of 103 million tons by 1970 and 217 million tons by 1980. Certain technological unknowns obscured the assurance of the various important markets; thus, other than show the prominent market possibilities, the study reveals a clear order of additional research needed to determine the reality of the estimates.

CFSTI PB-167-628

6.10.2

ECONOMIC EVALUATION OF A PROCESS TO PRODUCE ASHLESS, LOW-SULFUR FUEL FROM COAL

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.
Interim Report Oct 66-Jan 70.
Mar 70 149p
Contract: Di-14-01-0001-496
Monitor: OCR-53-INT-1
See also PB-234 041

Abstract: The report discusses the overall economic evaluation of a process developed by the Pittsburg & Midway Coal Mining Co. with emphasis on the use of the low-sulfur, ashless product as a power plant fuel for areas having restrictions on emission of sulfur dioxide to the atmosphere. The basic objective of the evaluation is to determine the selling price of the de-ashed coal product required to yield an adequate return on capital investment. Although the removal of both ash and sulfur are significant features, the process is generally referred to as a coal de-ashing process. (Modified author abstract)

NTIS PB-234 040/4

6.10.3

STUDY OF COST OF SULPHUR OXIDE AND PARTICULATE CONTROL USING SOLVING REFINED COAL

General Technologies Corp., Reston, Va. (151 400)

Shaver, R. G.

Apr 70 72p

Contract: PHS-CPA-22-69-82

Monitor: APTD-0575

Abstract: The primary purpose was to display the cost analysis data in such a way that it is readily adaptable to a large variety of real or hypothetical situations of heat or power generation so that direct comparisons can be made of the pollution control cost in specific situations by use of solvent refined coal to that of any other projected system for which control cost information is available. The heat content of SRC is considerably higher than the coal from which it is made and hence shipping costs are lower on an equivalent thermal basis. This is approximately 16,000 Btu/lb, which exceeds high quality anthracite or bituminous coal. Combustion chamber corrosion and slagging problems are directly reduced by its use. Since solvent refined coal can be liquified by heating and/or increasing its residual solvent oil content, there exists the option of firing as solid coal or as fuel oil. Lastly it is essentially a 'fail-safe' pollution control process so far as the combustion unit is concerned, since no unusual SO₂ pollution can be emitted due to breakdown or bypassing of equipment, as could occur with processes that cleanse combustion products. The potential market for solvent refined coal is difficult to predict largely because its use requires a long-term commitment on the part of producers to process it and on the part of the users primarily the electric power utilities to consume it. A level of production necessary for economy requires this. A processing cost of no more than 10 cents/MMBtu to convert bituminous coal to SRC should allow price-competitive access to over 60% of the current bituminous coal-fired combustion unit market. (author)

CFSTI PB-193 420

6.10.4

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL. VOLUME I. ENGINEERING STUDIES. PART 2 COG REFINERY ECONOMIC EVALUATION PHASE I

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.

Interim Report Oct 70-Feb 71

Apr 71 69p

Contract DI-14-01-0001-496

Monitor: OCR-53-INT-3

See also PB-234 043

Abstract: This report covers Phase I of an economic evaluation of a coal processing plant which would produce as its main products pipeline gas and a liquid suitable for use as a feedstock to a petroleum refinery. The plant would consist of a combination of the solvent refined coal process (SRC) and other processes sponsored by Office of Coal Research. The study (cont'd)

of a COG (coal, oil, gas) refinery was based on the belief that in such a combination intermediate streams from one process might be used very efficiently in one of the other processes.

NTIS PB-234 041/2

6.10.5

SOLVENT-REFINED COAL, ITS MERITS AND MARKET POTENTIAL

Jimeson, R. M., Grout, J. M.
Trans. Soc. Mining Eng. AIME 250 3 Sep 1971
194-8

6.10.6

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW SULFUR FUEL COAL. VOLUME I. ENGINEERING STUDIES. PART 3. COG REFINERY ECONOMIC EVALUATION. PHASE II

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.
Interim Report Feb-Nov 71
Jan 72 181p
Contract: DI-14-01-0001-496
Monitor: OCR-53-INT-4
See also PB-234 041 and PB-234 038

Abstract: The report was the result of a study to carry out a conceptual design and economic evaluation of a proposed process involving a combination of the solvent refined coal process (SRC) with other conversion processes. Divided into two distinct phases, the objective of Phase I was to develop the process combination with the best potential economics for a COG (coal, oil, gas) refinery employing the SRC process as primary coal conversion step. The report covers Phase II by summarizing a conceptual design of a commercial plant to carry out the processing steps, together with a detailed economic evaluation of the COG refinery.

NTIS PB-234 043/8

6.10.7

PITTSBURG AND MIDWAY COAL MINING COMPANY SOLVENT REFINED COAL PROCESS

Atkinson, C. D.
Discussion of process and costs
American Inst. of Min., Met., and Petrol. Engrs., Society of Min. Engrs., New York, 1973
Amer. Inst. of Mining, Metallurgical, and Petroleum Engineers, Prepr., paper 73-F-46

6.10.8

ECONOMIC EVALUATION AND PROCESS DESIGN OF A COAL-OIL-GAS (COG) REFINERY

Frank, M. E., (Chem. Systems, Inc., New York), Schmid, B. K.
Inst. of Gas Tech., Chicago, 1973

Clean Fuels from Coal

See Conf. 7309113

Symposium on Clean Fuels from Coal

Chicago, Illinois, USA

10 Sep 1973

Abstract: Process including coal preparation, solvent-refined coal process, hydrocracking and hydroconversion, bi-gas process, and cryogenic separation, economic evaluation.

6.10.9

COAL LIQUEFACTION

Perry, H.

Resources for the Future, Inc., Washington, D. C.

Am. Physical Soc., Top Conference on Energy, Proc, Chicago, Ill.

Feb 4-7, 1974 p43-55

Published by AIP (Conf. Proc. n 19), New York 1974

Abstract: Various methods for liquefaction of coal are reexamined. The current shortage of domestic clean energy sources and the very large reserves of indigenous coal have revived interest in the production of synthetic fuels from coal. One of the most important current needs is to produce a low-sulfur boiler fuel from high-sulfur coal. The Bureau of Mines is currently concentrating on development of the Synthoil process to convert coal into a very low-sulfur boiler fuel. A brief description of the process is given, with estimates of the production costs of a low-sulfur boiler fuel, 4.50 to 6.75 dollars per barrel. 2refs.

6.10.10

"COAL PROCESSING" PRODUCING CLEAN BOILER FUEL FROM COAL

O'Hara, J. B., Jentz, N. E., Rippee, S. N., Mills, E. A.

Ralph M. Parsons Co., Los Angeles, California

Chemical Engineering Prog. v 70 n 6 Jun 1974 p70-71

Abstract: The plant is designed to process 10,000 ton/day of coal. The plant contains two primary process units, a modified solvent refined coal (SRC) unit and a gasifier unit to produce syngas. The gasifier is capable of supplying reducing gases for an SRC-dissolver, an SRC-liquefield coal hydrogenator, and a light oil hydrogenator. The process description of the plant contains three major divisions; coal preparation, a coal liquefaction section, and a gasification section.
(cont'd)

The plant is designed to charge 10,000 ton/day of coal and to produce two low-sulfur liquid fuel streams as major products. With an alternate product objective, the plant could be converted to produce approximately 65 million cu. ft. /day of substitute natural gas (SNG). The plant receives 12,500 ton/day of coal. Estimated overall plant thermal efficiency is 63.5%. Estimated total fixed capital investment required is \$270 million, including total construction costs, home office engineering escalation and sales taxes. Estimated project total capital required including fixed capital investment, startup costs and recommended working capital amounts to about \$310 million.

6.10.11

TECHNICAL EVALUATION SERVICES, CLEAN LIQUID AND/OR SOLID FUELS FROM COAL

Parsons (Ralph M.) Co., Pasadena, Calif. Office of Coal Research, Washington, D. C.

Technical progress report. Oct 72-Aug 74

Nov 74 13p

Contract: DI-14-32-0001-1234

Monitor: OCR-82-INT-4

See also report dated 14 May 74, PB-237 216

Abstract: This report summarizes progress made on 13 various task assignments. The following are significant: a preliminary design and capital cost estimate report was prepared describing a coal conversion demonstration plant capable of producing 25,000 bbl/day of clean boiler fuels. Also completed was a preliminary process design and economic evaluation for a Fischer-Tropsch process plant to process 3,500 TPD of coal. Work is in the later stage of completion for a preliminary design and economic analysis of a conceptual nominal 25,000-TPD commercial COED-based pyrolysis plant with char gasification and electrical power generation. Reviews of process design, and construction progress are nearly completed for the SRC pilot plant located at Tacoma, Washington. Two designs of coal mines to supply feed to large-scale commercial coal conversion plants are essentially complete.

NTIS PB-237 216/7SL

6.10.12

BOILER MODIFICATION COST SURVEY FOR SULFUR OXIDES CONTROL BY FUEL
SUBSTITUTION

Acurex Corp., Mountain View, Calif. Aerotherm Div. National Environmental Research Center, Research Triangle Park, N.C.
Control Systems Lab.

Environmental protection technology series (final)

Schreiber, R., Davis, A., Delacy, J., Chang, Y., Lockwood, H.

Nov 74 121p

Report No: Aerotherm-74-113

Contract: EPA-68-02-1318

Project: EPA-ROAP-21ADE-010

Monitor: EPA/650/2-74-123

Abstract: The report gives results of a study to identify capital costs associated with converting industrial and utility boilers from conventional high-sulfur fossil fuels to low-sulfur products from selected coal conversion processes. The boilers of concern include all industrial and utility size equipment in the 10 to the 7th power to 10 to the 10th power Btu/hr capacity range. The substitute fuels include solvent refined coal (SRC in the solid and hot liquid (melted) phases as well as lower-Btu gas. The cost assessment methods used in the study showed that conversion to liquid SRC is the most expensive alternative. Converting coal-fired boilers to solid SRC is the least expensive alternative for these types of boilers. Between the costs of converting to SRC in either phase lie those costs for converting to the gaseous fuels. A significant result of the study is that the costs of all conversion strategies increase exponentially with boiler capacity: cost appears to be a weak function of boiler design.

NTIS PB-239 455/9ST

6.10.13

DEMONSTRATION PLANT, CLEAN BOILER FUELS FROM COAL: VOLUME III.
PRELIMINARY DESIGN/ECONOMIC ANALYSIS

Parsons (Ralph M.) Co., Pasadena, Calif. Office of Coal Research
Washington, D. C.

Interim Report

O'Hara, J. B., Rippee, S. N., Teeple, R. V.

Dec 74 60p

Contract: DI-14-32-0001-1234

Monitor: OCR-82-INT-1-Vol-3

Abstract: This report summarizes a preliminary economic analysis for a demonstration plant designed to produce clean boiler fuels from coal. The preliminary design and capital cost estimate were summarized in Volumes I and II. The demonstration plant will have the capacity to produce approximately 25,000 Bbls per day of liquid products from 10,000 TPD of washed sized coal. Investment and operating cost estimates are provided based on mid-1973 values. The fixed capital investment is estimated at \$226 million. Product selling prices required to provide a specified discounted cash flow return are included for various financial structures.

NTIS PB-529/2ST

6.10.14

THE POTENTIAL FOR DEVELOPING ALASKAN COALS FOR CLEAN EXPORT FUELS
PHASE I

Stanford Research Inst., Menlo Park, Calif. Office of Coal Research,
Washington, D. C.

Interim Report No. 1, Jan-Jul 74

Dec 74 25p

Contract: DI-14-32-0001-1516

Monitor: OCR-108-INT-1

Abstract: Economic feasibility of a coal conversion facility using the large Beluga coal reserves of Alaska is discussed. Although this study is site-related and one of a kind research, the data generated should have general application to coal resource development in other western coal mining areas. Even though the Alaskan reserves are somewhat remote from markets for coal and coal-derived fuels, the proximity of the recoverable coal reserves to deep water ports--unique to Alaska and Washington--promises some interesting and potentially low-cost transportation options for development.

NTIS PB-238 539/1st

6.10.15

NEW ENERGY TECHNOLOGY COEFFICIENTS AND DYNAMIC ENERGY MODELS. VOLUME I
SUMMARY; MAIN REPORT, AND APPENDICES

Just, J., Borko, B., Parker, W., Ashmore, A.
Mitre Corp., McLean, Va.

Jan 1975 NTIS

For Brookhaven National Lab, Upton, New York

6.10.16

NEW ENERGY TECHNOLOGY COEFFICIENTS AND DYNAMIC ENERGY MODELS, VOLUME II
APPENDICES

Just, J., Borko, B., Parker, W., Ashmore, A.
Mitre Corp., McLean, Va.

Jan 1975 NTIS

For Brookhaven National Lab, Upton, New York

6.10.16A
"SQUEEZING OIL AND GAS" FROM COAL

Thompson, Billy G.
Chilton's Oil Gas Energy v 1 n 2 Feb 1975 p 34-37

Abstract: The author evaluates the prospects of synthetic fuels obtained by coal gasification and coal liquefaction, as well as current projects undertaken or planned in the US. Seven coal gasification processes, and five coal-liquefaction programs are listed with a brief note on their status. The economics of western US coal, which is the most gasable in the country, are examined, and principal impediments of US coal gasification and liquefaction are indicated.

6.10.17
OIL EXTRACTION FROM POWER STATION FEED COAL. A UNIT APPROACH

Sligar, N.J., Lowe, A., Stewart, I.
University of Newcastle, Aust.
Inst. Eng. Aust. Mech. Chem. Eng. Trans. VMC 11 n 1-2, 1975 p-1-6

Abstract: A study has been made of siting a fluid bed pyrolysis coal liquefaction plant adjacent to a power station to which by-product char is fed. The plant is arranged to match 500 MW boiler-turbine units in size to preserve availability of the higher capital cost power generation equipment. Problems with the system are discussed together with an economic analysis for Australian conditions. Estimated costs indicate a high return on capital and estimated yield indicates that wide application of the system would make a substantial contribution to the Australian liquid fuel requirements. 12 refs.

6.10.18
MANPOWER, MATERIALS, EQUIPMENT, AND UTILITIES REQUIRED TO OPERATE AND MAINTAIN ENERGY FACILITIES

Bechtel Corp., San Francisco, Calif. National Science Foundation, Washington D. C. Stanford Research Inst., Menlo Park, Calif.
Center for Energy Studies
Final Report Oct 74-Mar 75
Mar 74 462p
Contract: NSF-C867
Project: SRI-3846
Monitor: 18
See also PB-245 382, and PB-245 383.

Abstract: Operating and maintenance manpower, materials, equipment and utility requirements for typical examples of energy production, transportation, and conversion facilities are given. The 67 facilities analyzed cover a wide range of activities, including mining, transportation, fossil fuel conversion, nuclear fuel production and reprocessing, and electric power generation.

NTIS PB-255 438/4ST

6.10.19

COMPARISON OF FLUE GAS DESULFURIZATION, COAL LIQUEFACTION, AND COAL GASIFICATION FOR USE AT COAL-FIRED POWER PLANTS

Kellogg (M. W.) Co., Houston, Texas Research and Engineering Development
Environmental Protection Agency, Research Triangle Park, N.C.

Office of Air Quality Planning and Standards.

Final Report

Apr 75 158p

Contract: EPA-68-02-1308

Monitor: EPA/450/3/-75/047

Abstract: The report presents a technical and economic comparison of the use of flue gas desulfurization, coal liquefaction, and coal gasification as a means of preventing SO₂ emissions at coal-fired power plants. The report assesses the status of technology, process complexity, process flexibility, environmental effects, installation difficulties, energy conversion efficiency, manpower requirements, and economics of each approach to controlling SO₂ as it would be applied to electric power plants. Three different flue gas desulfurization systems were evaluated as well as one coal liquefaction and one coal gasification processes. Two power plant cases are evaluated, an existing 500 MW plant operating at 60 percent load factor and a new 1,000 MW plant operating at 80 percent load factor.

NTIS PB-264 536/4ST

6.10.20

TECHNICAL COEFFICIENTS FOR INPUTS TO NEW ENERGY TECHNOLOGIES

Swift, M. A.

Illinois University, Urbana; Center for Advanced Computation

University of Illinois at Urbana-Champaign, Center for Advanced Computation

Brookhaven National Laboratory, Urbana, Ill. 61801 BNL. Upton, N.Y. 11973

Apr 1975 NTIS

Abstract: The derivation of input-out technical coefficients is described for inputs to four new energy supply and conversion technologies from non-energy technologies for use in the modified "energy products" energy/employment policy model at the University of Illinois center for advanced computation. The four new technologies are solvent-refining of coal, oil shale mining and retorting. High temperature gas-cooled reactor electricity generation, and cogas combined cycle electricity generation. The coefficients are given in units of dollars per billion Btu and represent the inputs from nonenergy sectors (e.g. manufacturing, transportation, services) required per unit of production by one of the energy supply technologies. The 85 non-energy sectors included are based on the bureau of economic analysis 83 sector input-output structure with minor disaggregations. The paper also represents the input-output coefficients for inputs from energy sectors to these four new technologies as well as to one additional technology: coal gasification.

6.10.21

LIQUID FUELS FROM COAL

Hydrocarbon Process v 54 n 5 May 1975 p119-121

Abstract: Liquid and gaseous hydrocarbons can be produced from coal by uptake of hydrogen or by elimination of carbon. The principal possibilities for producing fuels with an increased hydrogen content from coal can be designated as coal pyrolysis (coking and low temperature carbonization), coal hydrogenation (plus hydrogenative extration) and hydrocarbon synthesis starting from the coal gasification products ($\text{CO} + \text{H}_2$). In addition, coking will gain increasing significance in order to save petroleum products used in ore reduction. This review report is presented under headings: present trends in hydrogenation: hydrocarbon synthesis: development trends in coal gasification and coal liquefaction; and economic considerations. 15 refs.

6.10.22

CURRENT STATUS OF COAL LIQUEFACTION TECHNOLOGY

Holloway, F. A. L., Siegel, H. M.
Exxon Corp.

World Energy Conf., 9th. Trans. Pap and Discuss. Detroit, Mich.
Sep 23-27 1974 v4 p337-358. Published by US National Commission of
the World Energy Conference, New York, N.Y. 1975

Abstract: Technical status of producing liquid fuels from coal is given estimates by the U.S. National Petroleum Council in 1972 indicate that coal liquids could be produced in the United States in mine-mouth plants feeding surface-mined western coal for a cost at the plant of about \$63/m³ (\$10.00 bbl) in 1980 dollars. This would appear to be competitive with imported natural crude. Molecular structure of coal, and tables illustrate analysis. 16 refs.

6.10.23

H-COAL PILOT PLANT PROGRAM

Stotler, H. H.

Hydrocarbon Res., Inc., New York, N.Y.

Coal Process Technol, v 2 p15-19 Publ. by AIChE, New York, N.Y. 1975

Abstract: Following satisfactory results from bench-scale and process development work, the catalytic liquefaction method is now moving toward full pilot scale fun in Kentucky. The aims of the pilot plant program are given: Economic summaries of hydrogen produced by Lurgi gasification, partial oxidation of vacuum still bottoms, and separation from solids are presented.

6.10.24

COST MODELING EVALUATES COAL LIQUEFACTION PROCESSES

Tackett, L. P., Nichols, D. G.

W. Va. University, Morgantown

Coal Process Technol. v 2 p25-31 Publ. by AIChE, New York, N.Y. 1975

Abstract: A very meaningful and valid economic comparison among coal liquefaction processes can be made if it is based upon the same feed coal, the same product distribution, and same costing techniques. The objective of this study was to compare three coal liquefaction processes using the same basic assumptions. The comparison used a computerized model of each of the processes evaluated. They were Hydrocarbon Research, Inc.'s H-Coal process, Pittsburgh and Midway Coal Co.'s SRC process, and the U.S. Bureau of Mines' Synthoil process. These three were selected owing to their great promise for commercialization as reflected by their present state of development and the existence of substantial currently active programs supporting their further development. The models were developed to provide a capability for process performance and cost evaluation over a wide range of process capacities with a minimal engineering manpower requirement. The results from the models are depicted graphically. 25 refs.

6.10.25

PRESENT STATUS OF THE H-COAL PROCESS

Johnson, C. A., Chervenak, M. C., Johanson, E. S., Stotler, H. H., Winter, O. W., R. H.

Hydrocarbon Res. Inc, Trenton, N.J.

Clean Fuels from Coal Symposium, 2nd, Pap, Ill. Inst. of Technology, Chicago, Jun 23-27, 1975 inc. Sel Pap from Symposium, 1st Ill Inst.

of Technology, Chicago, Sep 10-14, 1973 Publ. by Inst. of Gas Technology, Chicago, Ill. 1975 p525-551

Abstract: The technical and economic feasibility of the H-Coal Process for the conversion of coal to liquid products has been demonstrated in numerous publications. This paper discusses the present status of the process. The H-Coal process utilizes an ebullated bed reactor to continuously convert coal in a catalytic hydrogenation system. Bench-scale and process development units are described briefly. Experimental results are presented for operations of two ranks of coal (Illinois no. 6 and Wyodak) and two modes of operation (synthetic crude and low-sulfur fuel oil production). A new coal gasification process is proposed as the means to provide the required hydrogen for the H-Coal process. An economic summary is presented for three types of commercial plants and a prototype plant route to commercialization is described.

6.10.26

ECONOMIC EVALUATION AND PROCESS DESIGN OF A COAL-OIL-GAS (COG) REFINERY

Frank, M. E., Schmid, B. K.

Chem. Syst. Inc., New York, N.Y.

Clean Fuels from Coal Symp. 2nd, Pap., Ill. Inst. of Technology,
Chicago, Jun 23-27, 1975 inc. Sel. Pap. from Symp, 1st. Ill. Inst.
of Technology, Chicago, Sep 10-14 1973 Published by Inst. of Gas
Technology, Chicago, Ill., 1975 p553-576

Abstract: This paper deals with Chem. Systems' economic evaluation and conceptual design of a processing complex for conversion of coal to oil and gas. Designated as a COG (Coal, Oil, Gas) Refinery, this complex shows considerable promise for production of high Btu pipeline gas, a liquid feedstock for a petroleum refinery and a low-sulfur fuel for power plants. One of the more significant features of this type of complex combining several processes is that a large part of the methane is obtained together with the liquid products by direct hydrogenation, thus eliminating a costly methanation step.

6.10.26A

SOLID-LIQUID SEPARATION IN COAL LIQUEFACTION PROCESSES

Batchelor, James D. and Shih, Christopher

Presented at the 68th National Meeting

American Institute of Chemical Engineers

Los Angeles, California, November 18, 1975

Abstract: Comparative economics of rotary precoat filter, pressure leaf precoat filter, solvent deashing and centrifugation as a means of solid-liquid separation in coal liquefaction processes are given. None of the technique is attractive. A hybrid method of separation or all distillate product slate are recommended alternatives.

6.10.27

PROSPECTS FOR COAL AS A DIRECT FUEL AND ITS POTENTIAL THROUGH APPLICATION OF LIQUEFACTION AND GASIFICATION TECHNOLOGY

Bowden, J. R.

Conoco Coal Development Co., Stamford, Conn.

Energy Sources v3 n1 1976 p1-11

Abstract: During the next 20 years, domestic energy consumption will grow at a rate of somewhat less than 3% per year. Coal production can grow 75% in this period, which will increase coal's contribution to our energy budget from 18 to 27%. Principal opportunities and constraints rest in the political arena as we try to accommodate our social concerns with physical and economic realities. No technical fix is on the horizon which will permit coal to be converted cheaply to our present definition of a clean fuel. For processes other than flue-gas desulfurization, value added during conversion exceeds the basic cost of the energy in coal. All conversion costs lie within the range of uncertainty of the untried processes and no process has emerged as clearly superior.

6.10.28

COAL-DERIVED CHEMICALS COULD OPEN NEW FRONTIERS

Rao, K. V., Skeist, I.

Skeist Lab Inc., Livingston, N.J.

Oil Gas Journal v 74 n 5 Feb 2, 1976 p90-93

Abstract: New coal-conversion technology is shortening the route from raw material to end product. By circumventing intermediate steps, traditional for petroleum, coal will become a competitive source for many basic chemicals. Particularly promising, in addition to combination fuels/ chemicals operations, are syngas, coal-chemical complexes, and flash hydrogenation to produce benzene. Coal-derived chemicals can provide the basis of a new set of economics in the \$35-billion petrochemical industry. Over the next 10 years, a reborn coal-chemicals industry based on important technological advances promises to quadruple coal's share of markets for a dozen key chemicals, from 1.6% in 1975 to 6.6% in 1985. Since total volume of these chemicals from all sources is expected to double over this decade, there will be an eightfold increase in coal chemicals.

6.10.29

CONCEPTUAL COMMERCIAL DESIGN AND COMMERCIAL FEASIBILITY EVALUATION FOR CLEAN BOILER FUEL FACILITY. VOLUME I. CONCEPTUAL COMMERCIAL DESIGN

Dravo Corp., Pittsburgh, Pa. Chemical Plants Div. Energy Research and Development Administration

Feb 76 236p

Contract: E(49-18)-1772

Monitor: 18

Abstract: Dravo Corporation was requested by ERDA to perform an independent grass roots design and a technical and economic evaluation of the Coalcon Process as conceptualized in Coalcon's Process Evaluation Report dated August 15, 1975. The Dravo design was to consist of two parallel operating trains and should have a plant capacity as large as existing technology and sound engineering judgement will permit. A technical and economic analysis of factors influencing total plant capacity led to a nominal capacity of 50,000 tons/day as maximum for a two-line operation. Energy product output distribution from such a facility is tabulated (SNG, LPG, Light Oil, Fuel Oil and By-products). Major differences between the Dravo and Coalcon designs occurred in the areas of storage, char gasification, fractionation, and steam generation. Storage for raw coal and plant products was increased from four to thirty days. A pressurized fluid bed gasifier was selected for char gasification based on an economic trade-off analysis. The plant fractionation
(cont'd)

system was expanded to include stabilization of products required to meet product specifications or stability for outdoor storage. Steam was generated by burning desulfurized fuel and process gas heating requirements were satisfied with separate heaters. Hot flue gas was not withdrawn from the boiler radiant section as in the Coalcon design. Other differences and the justification for changes are included in Volume II. Capital costs for a plant as described were estimated at 1.2 billion dollars with 1.6 billion dollar total capital requirements. The Dravo evaluation revealed several other areas of the design where further study is required to fully assess their technical and economic impact.

NTIS FE-1772-13 (V.1)

6.10.30

CONCEPTUAL COMMERCIAL DESIGN AND COMMERCIAL FEASIBILITY EVALUATION FOR CLEAN BOILER FUEL FACILITY. VOLUME II. SELECTIONS AND EVALUATIONS.

Final report

Dravo Corp., Pittsburgh, Pa. Chemical Plants Div. Energy Research and Development Administration

Feb 76 187p

Contract: E(49-18)-1772

Monitor: 18

Abstract: Backup studies related to the choice of plant capacity, choice of 22 process types or operations and trade-off studies on 7 processes are reported.

NTIS FE-1772-13 (V.2)

6.10.31

CONCEPTUAL COMMERCIAL DESIGN AND COMMERCIAL FEASIBILITY EVALUATION FOR CLEAN BOILER FUEL FACILITY. VOLUME III. COMMERCIAL FEASIBILITY FINAL REPORT

Dravo Corp., Pittsburgh, Pa. Chemical Plants Div. Energy Research and Development Administration

Feb 76 52p

Contract: E(49-18)-1772

Monitor: 18

Abstract: The estimated total plant investment for the 50,000 T/D base case plant design is \$1.2 billion. The estimated total capital required, including interest during construction, start-up, costs, and working capital is \$1.6 billion. The capital estimate is based on current pricing (late 1975) for process equipment and applying appropriate factors derived from Dravo experience with similar type facilities to obtain the completed plant costs. Based on a typical eastern run-of-mine bituminous coal (Pittsburgh No. 8), priced at \$20/ton and using the utility financing method, the calculated average product fuel price is \$2.70MM Btu. This is equi-
(cont'd)

valent to a fuel oil price of \$14.77/bbl or \$0.35/gal. This is only slightly higher (9 percent, certainly within the estimate accuracy) than current pricing for low sulfur No. 6 fuel oil (\$13.50/bbl, East Coast). While the price of imported oil is not precisely predictable, and may cycle over short periods, the general trend is for a steady increase. The factors employed in the utility financing method are based on a variation of the familiar AGA/OCR formula, with a debt/equity ratio of 75/25, a 9 percent interest rate on debt, and a 15 percent net return on equity. The calculations assume a 20-year project life, a straight line depreciation of 5 percent/year of the depreciable assets, and a federal income tax rate of 48 percent. Plant availability is based on 330 days/year. The coal requirement is 16.5 MM t/yr with an as-received gross heat value of 11,760 Btu/lb. Primary products include: heavy fuel oil, SNG, and the LPG fraction. By-products include: high-sulfur light oil, elemental sulfur, phenols, pyridine, and ammonia. The by-products are valued at current published prices, adjusted for any appreciable effects resulting from quality differences or volume availability. A calculated thermal efficiency of 62.43 percent includes the heat value of the primary as well as the by-products.

NTIS FE-1772-13(V.3)

6.10.32

PRELIMINARY ECONOMIC ANALYSIS OF SRC LIQUID FUELS. PROCESS PRODUCING 50,000 BARRELS PER DAY OF LIQUID FUELS FROM TWO COAL SEAMS: WYODAK AND ILLINOIS NO. 6

Bureau of Mines, Morgantown, W. Va. Process Evaluation Group. Energy Research and Development Administration.

May 76 192p

Report No: FE-2083-8

Monitor: 18

Abstract: This report is divided into two sections. The first deals with Wyodak coal, and the second deals with Illinois No. 6 coal. An abstract was prepared for each section.

(1) An economic evaluation was made of an integrated Plant sized and designed to produce 50,000 BBL/steam day of liquid products from Wyodak run-of-mine (ROM) coal. The primary products consist of 45.978 BBL/day of two grades of clean boiler fuels (0.1 and 0.2 percent sulfur) and 4,022 BBL/day of a high-grade naptha for a total of 50,000 BBL/day, secondary products are 222 tons/day of sulfur and 10,000 KW-HR/hour of electric power. (The process design basis and yields for this plant were taken from work done by the Ralph M. Parsons Company for the office
(cont'd)

of coal research.) The total capital investment is estimated to be \$710,601,700 of approximately \$42.52/annual barrel of liquid fuel production capacity on the basis of a 330-day operating year for the plant and allowing credit for sulfur and excess power produced, the average selling price of the boiler fuel plus naphtha per barrel of primary product and per MMBTU heating value of the product is given with coal cost and discounted cash flow (DCF) rates as parameters.

(2) An economic evaluation was made of an integrated plant sized and designed to produce 50,000 BBL/stream day of liquid products from Illinois No. 6 run-of-mine (ROM) Coal. The primary products consist of 45,978 BBL/day of two grades of clean boiler fuels (0.2 and 0.5 percent sulfur) and 4.022 BBL/day of a high grade naphtha for a total of 50,000 BBL/day. Secondary products are 634 tons/day of sulfur and 22,000 KW-HR/hour of electric power. (The process design basis and yields for this plant were taken from work done by the Ralph M. Parsons company for the office of coal research.) The total capital investment is estimated to be \$7000,649,200 or approximately \$42.45/annual barrel of liquid fuel production capacity, on the basis of a 330-day operating year for the plant and allowing credit for sulfur and excess power produced, the average selling price of the liquid fuel plus naphtha per barrel of primary product and per MMBTU heating value of product is given, with coal cost and discounted cash flow (DCF) rates as parameters.

NTIS ERDA-76-55

6.10.33

1985 TECHNICAL COEFFICIENTS FOR INPUTS TO ENERGY TECHNOLOGIES

Brookhaven National Lab., Upton, N.Y. Energy Research and Development Administration.

Lukachinski, J., Tessmer, R. G., Jr.

Jun 76 38p

Contract: E(30-1)-16

Monitor: 18

Abstract: This report describes the incorporation of input-output technical coefficients for five new energy supply and conversion technologies as estimated by the MITRE Corporation into a 110-sector Energy I--0 Model. The five new technologies are solvent refining of coal, oil shale mining and retorting, high temperature gas-cooled reactor electricity generation, high-BTU coal gasification, and COGAS combined-cycle electricity generation. Incorporation of seven existing energy supply and conversion technologies is also described: crude oil and gas extraction, coal mining, refined petroleum products, pipeline gas, fossil electric generation, and hydroelectric generation. Non-energy input coefficients are given in units of 1967 \$/10 exp 6 BTU and represent the inputs in constant 1967 dollars from non-energy sectors (e.g. manufacturing, trans-
(cont'd)

portation, services) required per 10 exp 6 BTU of energy production by each of these energy supply technologies. The 90 non-energy sectors included are based on the Bureau of Economic Analysis 83 sector input--output structure for 1967 with minor disaggregations. Energy input coefficients are given in units of BTU/BTU.

NTIS BNL-50532

6.10.34

CLEAN FUELS FROM COAL ARE EXPENSIVE

Katell, S., White, L. G.,
W. Va. University, Morgantown
Hydrocarbon Process v55 n7 Jul 1976 p85-90

Abstract: This paper presents cost analysis of fuels obtained from coal. Two principal processing approaches have been considered: conversion to gas suitable for inclusion in established natural gas systems and production of a clean liquid. Costs are based on construction of either a 250 MMscfd gas plant or a 50,000 bpd liquid plant according to reported needs for several processes of each type. Selling prices for productions have been determined for various costs of coal discounted cash flow rates (DCF) of 12, 15 and 20 percent. Pollution abatement consideration has been incorporated in plant design but no inflation factor has been considered. It is demonstrated that product costs from coal conversion will exceed \$2/MMBtu (1975 prices) and can reach as much as \$5.45/MMBtu under certain conditions. An examination of process choices and other controlling variables for this capital intensive but necessary new industry suggest prices that fall into a \$3.50/MMBtu range for most practical solutions based on best available development plant data. Details are given for Synthane coal gasification process (from Eastern Coal) and Synthoil Liquefaction process (from both Eastern and Western Coals).

6.10.35

SULFUR COMPOUND CLEANUP: TRADE-OFFS IN SELECTING SO_x EMISSION CONTROLS

Jimeson, R. M. (Federal Power Commission, Washington, D. C.)
Maddocks, R. R.
Low Sulfur Western Coal
Chemical Engineering Prog. 72/8/Aug 1976 p80-88

Abstract: No sulfur oxide pollution control system is universally applicable. Flue gas desulfurization units appear to be most appropriate for large boilers that can operate compatibly with FGD systems at high load factors throughout most of their life. In contrast, solvent-refined coal is most appropriate for medium to small boiler units where load factors over the life of the plant are expected to be less than 65 percent, or where it is desirable to dedicate a utility's capital to electric generating equipment. As a corollary, SRC would be appropriate as the
(cont'd)

clean fuel in an intermittent control system (ICS) plan. SRC would be burned only during poor meteorological conditions that occur about 10 percent of the time during the year. Thus, ICS is tantamount to SRC being burned at low load factor/and considerable savings in sulfur oxide emission control costs are possible without jeopardizing ambient air quality standards, the use of low sulfur western coal appears economically feasible as a sulfur control method for some plants within a range of 1200 miles. The zone of equal trade-off appears to be located near the Mississippi river

6.10.36

COAL UTILIZATION: THE EMISSIONS CONTROL ALTERNATIVE

Weiss, L. H.

Chem Syst Inc., New York, N.Y.

Intersoc Energy Convers Eng Conf, 11th, Proc, State Line, Nev.,

Sep 12-17 1976 Published by AIChE, New York, N.Y., 1976

v 1 SAE Pap 769049 p309-314

Abstract: The direct combustion of coal produces airborne emissions of sulfur oxides (SO_x). The main alternatives for limiting SO_x emissions are conversion of the coal to a clean fuel or flue gas desulfurization (FGD). The most economic coal conversion processes for power generation are Lurgi gasification and H-Coal liquefaction. Three representative FGD processes were selected for comparison. The unit cost estimated for electric power generation using the limestone slurry FGD process is 45.9 mil/kwh, for the Wellman-Lord sodium-based FGD process is 46.7 mil/kwh, and for the Atomics International ACP FGD process it is 44.6 mil/kwh in 1980 costs. Immediate Btu gas from a Lurgi installation gives electricity at 62.1 mil/kwh on the same basis. Similarly, syncrude from an H-Coal plant has a generation cost of 57.5 mil/kwh. 8 refs.

6.10.37

20,000 TPD SOLVENT REFINED COAL PLANT. A PROCESS ENGINEERING AND ECONOMIC STUDY FOR SOUTHERN SERVICES, INC. PROJECT 10,895. VOLUME I AND II.

Catalytic, Inc., Philadelphia, Pa. October 1976

A process engineering and economic study of the SRC process at 20,000 TPD level was made. This study incorporates all available information from Wilsonville, Tacoma and other sources. It also distills the experience gained by Catalytic over the past few years in the coal processing area.

This study consists of preliminary process engineering that includes coal received in barges, pulverized to -50 mesh and dried to 2% moisture. Coal is dissolved in a carrier solvent (S:C-1.6:1) at 1750 psig and 825°F in a continuous dissolver. The reaction mixture is degassed. It is filtered in

(Cont'd)

a batch mode using several 5500 sq.ft. Funda filters. The filter cake is dried in the filter and charged to a gasifier for conversion to hydrogen. The filtrate is fractionated to recover light, medium and heavy oils, as well as SRC. The gases and oils are sold as clean fuel or petrochemical feed stock. Part of the SRC is used as plant fuel. The rest is sold as power plant fuel. Waste treatment systems are provided to process waste gases and waste water effluents.

The process engineering study (Volume I) presents process description, process flow sheets, material balances, major equipment specifications and utilities requirements. A plot plan is also presented.

In a companion volume (Volume II), installed plant cost developed from the cost of major equipment is generated. Costs for H₂ plant and waste treatment systems were developed from published data using well-known scale-up factors. Also presented in this volume is an operating cost estimate for the plant.

6.11 U. S. ERDA REPORTS

Publications by U.S. E.R.D.A. on its coal liquefaction activities and reports by Ralph M. Parsons Co. on technical evaluation services on coal liquefaction processes are included in this section.

6.11.1

DEMONSTRATION PLANT - CLEAN BOILER FUELS FROM COAL - PRELIMINARY
DESIGN/CAPITAL COST ESTIMATE - VOLUME I

Parsons (Ralph M.) Co., Los Angeles, Calif. (277 100)

Interim Report No. 1, October 1972 - September 1973

21 September 1973 87p

CONTRACT: DI-14-32-0001-1234

MONITOR: OCR-82-INT-1-Vol-1

See also Volume 2, PB-234 321.

Abstract: This is the first of 2 volumes dealing with a demonstration plant to produce clean boiler fuels from coal. The estimated capital investment for the demonstration plant was fixed at \$270-million. The plant will have the capacity to process 10,000 tons of coal per day, and produce approximately 25,000 barrels of liquid products. The primary products consist of two grades of clean boiler fuels, with secondary products being a high-grade naphtha and sulfur. The liquid boiler fuels will have an energy content of about 145 billion Btu's per day, which can generate 620 megawatts of electrical energy. The objectives included an estimate of the earliest date at which the coal conversion plant could be mechanically complete and ready to begin production operations. Volume II is available as PB-234 321.

NTIS PB-234 165/9

6.11.2

DEMONSTRATION PLANT - CLEAN BOILER FUELS FROM COAL - PRELIMINARY DESIGN/
CAPITAL COST ESTIMATE - VOLUME II

Parsons (Ralph E.) Co., Los Angeles, Calif. (277 100)

Interim Report No. 2, October 1972 - December 1973

21 December 1973 107p

CONTRACT: DI-14-32-0001-1234

MONITOR: OCR-82-INT-1-Vol-2

See also Volume 1, PB-234 165

Abstract: This second volume completes the technical report for the preliminary design and capital cost estimate of a demonstration plant to produce clean boiler fuels from coal. The volume includes various flow diagrams and material balance data necessary to substantiate the preliminary design bases of the demonstration plant as referenced and presented in Volume I (PB-234 165). As defined, the demonstration plant will have the capacity to process 10,000 tons of coal per day and to produce approximately 25,000 barrels of liquid products.

NTIS PB-234 321/8

6.11.3

DEMONSTRATION PLANT, CLEAN BOILER FUELS FROM COAL: VOLUME III. Preliminary Design/Economic Analysis

Parsons (Ralph M.) Co., Pasadena, California *Office of Coal Research, Washington, D.C.

Interim rept.

Author: O'Hara, J.B., Rippee, S.N., Teeple, R.V.

Dec 74 60p

Contract: DI-14-32-0001-1234

Monitor: OCR-82-INT-1-Vol-3

Abstract: This report summarizes a preliminary economic analysis for a demonstration plant designed to produce clean boiler fuels from coal. The preliminary design and capital cost estimate were summarized in Volumes I and II. The demonstration plant will have the capacity to produce approximately 25,000 Bbls per day of liquid products from 10,000 TPD of washed sized coal. Investment and operating cost estimates are provided based on mid-1973 values. The fixed capital investment is estimated at \$226 million. Product selling prices required to provide a specified discounted cash flow return are included for various financial structures.

NTIS PB-238 529/2ST

6.11.4

COAL LIQUEFACTION. Quarterly Report, Jan-March 1975

Energy Research and Development Administration, Washington, D.C.
Office of Fossil Energy.

1975 47p

Monitor: 18

Abstract: This report consists of eight sections in addition to an executive summary and a glossary. Each section was abstracted and indexed separately.

NTIS FE-1775-2

6.11.5

TECHNICAL EVALUATION SERVICES, CLEAN LIQUID AND/OR SOLID FUELS FROM COAL.
Interim Technical Progress Report for the Period October 1972-August 1974

Parsons (Ralph M.) Co., Pasadena, California

Aug 74 9p

Contract: 14-32-0001-1234

Monitor: 18

Abstract: No abstract available.

6.11.6

TECHNICAL EVALUATION SERVICES, CLEAN LIQUID AND/OR SOLID FUELS FROM COAL.

Parsons (Ralph M.) Co., Pasadena, California Office of Coal Research,
Washington, D.C.

Technical progress rept. Oct 72-Aug 74.

Nov 74 13p

Contract: DI-14-32-0001-1234

Monitor: OCR-82-INT-4

See also report dated 14 May 74, PB-237 216.

Abstract: This report summarizes progress made on 13 various task assignments. The following are significant: A preliminary design and capital cost estimate report was prepared describing a coal conversion demonstration plant capable of producing 25,000 bbl/day of clean boiler fuels. Also completed was a preliminary process design and economic evaluation for a Fischer-Tropsch process plant to process 3,500 TPD of coal. Work is in the later stage of completion for a preliminary design and economic analysis of a conceptual nominal preliminary design and economic analysis of a conceptual nominal 25,000-TPD commercial COED-based pyrolysis plant with char gasification and electrical power generation. Reviews of process design, mechanical design, and construction progress are nearly completed for the SRC pilot plant located at Tacoma, Washington. Two designs of coal mines to supply feed to large-scale commercial coal conversion plants are essentially complete.

NTIS PB-237 216/7SL

6.11.7

PRELIMINARY DESIGN SERVICES RESEARCH AND DEVELOPMENT REPORT NO. 114,
July-Sept 1975. Interim Report No. 2

Parsons (Ralph M.) Co., Pasadena, California

Nov 75 17p

Contract: E(49-18)-1775

Monitor: 18

Abstract: The objective of the work is to develop preliminary designs and economic evaluations for a number of coal conversion plants. The following designs are included in the scope of work: a conceptual commercial plant for a Coal-Oil-Energy-Development (COED) plant; an Oil/Gas plant to commercial-scale Fischer-Tropsch plant with motor fuel and SNG as the main products; a commercial scale plant for the production of solvent-refined coal (SRC); a Coal Oil Gas Refinery (COG) to produce clean liquids, gas and electrical power generating capacity; and a facilities complex capable of demonstrating the commercial feasibility of a variety of coal conversion processes that show promise during pilot plant operations. The following facilities will be considered: conversion of coal to low to high Btu fuel gas methanol/motor fuel by Fischer-Tropsch process; and clean liquid fuels by alternate liquefaction processes. In addition, supporting efforts will be provided to the above activities. These efforts include planning and progress monitoring, equipment, and environmental factors.

NTIS FE-1775-2

6.11.8

TECHNICAL ASSISTANCE SERVICES

White, P.C., Zahradnik, R.L., Cochran, N.P.

Energy Research and Development Administration, Washington, D.C.

Office of Fossil Energy

Parsons (Ralph M.) Co., Pasadena, California

1975

Coal Demonstration Plants

ERDA 112-75/1

During the Quarter, Parsons continued the development of conceptual designs for the COED, SCR-Based Oil-Gas, Fischer-Tropsch, and COG plants and for coal mining and preparation facilities. The COED design was nearly completed. Work on technical evaluations included development of proposals for equipment and control apparatus/oil-solid and gas-solid separation, gasification, and pressure recovery turbine systems were of particular concern. Parsons also reviewed and updated a list of construction materials for the oil-gas plant, analyzed corrosion and erosion problems, and reviewed the general approach required for the environmental control program.

6.11.9

COAL CONVERSION AND UTILIZATION R AND D IN ERDA

Energy Research and Development Administration, Washington, D.C.
Division of Coal Conversion and Utilization.

Zahradnik, R.L.

1975 13p

Monitor: 18

Meeting of the Society of Mining Engineers, Salt Lake City, Utah, USA,
12 Sept. 1975.

Abstract: The coal conversion research programs of the U.S. Energy Research and Development Administration are described briefly. The programs are based on the large coal reserves in the U.S. and forecasts of the future requirements of clean gaseous and liquid fuels for power generation, transportation and residential and industrial uses. Funding has been requested to initiate conceptual design activities during FY 76 for a low Btu gasification demonstration plant, and for a high Btu gasification demonstration plant. These plants will build on experience obtained in gasification pilot plants, and represent major advances in the development of coal conversion technology. The Coal Conversion and Utilization Program currently has over 100 contracts outstanding with total value of over \$400 Million. Industry is contributing over 25 percent of these funds. We hope to maintain the present standard for cooperative joint funding which anticipates one-third private, two-thirds Federal, for pilot plants and 50-50 for demonstration plants. Our participants include many aspects of American industry: oil and gas companies, chemical companies, utilities, universities, research centers, and trade associations. In addition to the contractors performing the major project work described, we have contractors performing engineering evaluations, systems studies, planning studies, and environmental analyses. We also have several Interagency Agreements and some international agreements for cooperation in areas of mutual interest.

NTIS CONF-750946-20

6.11.10

COAL LIQUEFACTION. Quarterly Report, Oct-Dec 1975

Energy Research and Development Administration, Washington, D.C.
Office of Fossil Energy.

1976 59p

Monitor: 18

Abstract: Progress on US ERDA's coal liquefaction research and development programs is reported. This included operation of the SRC pilot plant to produce 400 tons of specification solvent-refined coal, process development efforts related to the Synthoil process, site selection and engineering for the H-coal process pilot plant, and renovation of the Cresap test facility (for testing components). Research and development studies were carried out
(Cont'd)

on the carbonization step of the clean coke process and on the liquefaction of coal by direct hydrogenation. Studies on solids removal from coal-derived liquids continued. Studies on hydrocarbonization of coal and on the carbonization of residues continued. Studies on the use of coal-derived liquids as feedstocks for the production of organic chemicals continued with distillation fractionation, hydrotreatment and characterization and analysis of samples, products and intermediates.

ERDA-76-33-4

6.11.11

COAL CONVERSION AND UTILIZATION. 1975 Technical Report

Energy Research and Development Administration, Washington, D.C.

Office of Fossil Energy.

1976 221p

Monitor: 18

Abstract: US ERDA's 1975 programs and progress in coal gasification, coal liquefaction, fluidized-bed combustion and combined power cycles are reviewed. Some related applications or problem areas are also discussed: hydrogen production by the steam-iron process, desulfurization, mathematical modeling, filtration of coal liquids, high temperature dust control and various other combustion projects.

NTIS EDRA-76-86

6.11.12

COAL LIQUEFACTION. Quarterly Report, Jan-March 1976

Energy Research and Development Administration, Washington, D.C.

Office of Fossil Energy.

1976 63p

Monitor: 18

Abstract: ERDA's coal liquefaction program is reviewed, especially the progress with several pilot plant operations. Other items involve the possible recovery of organic chemicals from coal liquids, the filtration of coal liquids, some experiments on hydrogenation and carbonization, and renovation of the Cresap materials and equipment test facility.

NTIS ERDA-76-95-1

6.11.13

PRELIMINARY DESIGN SERVICES COAL CONVERSION DEMONSTRATION PLANTS.

Research and Development Report No. 114. Quarterly Report, April-June 1976

Energy Research and Development Administration, Washington, D.C.

Division of Biomedical and Environmental Research.

Sept 76 21p

Contract: E(49-18)-1775

Monitor: 18

Abstract: Engineering, design and evaluation services are listed. These involve work on various plants as follows: COED process plant liquid fuels plus substitute natural gas plant, Fischer-Tropsch synthesis plant, solvent-refined coal plant, a coal oil gas (COG) refinery, and a facilities complex capable of demonstrating the commercial feasibility of a variety of coal conversion processes. Support efforts include planning, progress monitoring, equipment development and environmental factors.

NTIS FE-1775-5

6.12 WILSONVILLE SRC PILOT PLANT REPORTS

Listed here are various periodic progress reports published on the operation of the Wilsonville SRC pilot plant. Several papers on the pilot plant operation are also included.

6.12.1
PROGRESS IN COAL LIQUEFACTION

Sooter, M.C.
Catalytic, Inc., Philadelphia
Energy Commun.
January 75 309-317p

Abstract: This report summarizes some of the history of solvent refined coal liquefaction processes, gives a description of the process now being piloted at Wilsonville, Alabama, and records some of the early success of the Wilsonville plant.

6.12.2
SOLVENT REFINING OF COAL

Harrison, W.B., Huffman, E.L.
Pilot Plant Studies
Amer. Chem. Soc., Div. Fuel Chem.
Washington, D.C. 1974
Paper 25
167. ACS National Meeting
Los Angeles, California
31 Mar-5 Apr 1974

6.12.3
SRC TECHNICAL REPORT NO. 5
ANALYSIS OF OPERATIONS FOR RUNS 6, 7, and 8
PERIOD - 17 JUNE THROUGH 26 AUGUST 1974
A. G. Draeger, et. al.
SOLVENT REFINED COAL PILOT PLANT
WILSONVILLE, ALABAMA

Abstract: Runs 6, 7, and 8, covering a 26-day operating period for the SRC Pilot Plant between 25 June and 4 August 1974, produced a total of 44 tons of specification-grade material using West Kentucky No. 14 seam coal.

Substantially improved Filter performance was demonstrated by the fact that specification-grade extract was produced in quantity. Filtration performance was not significantly affected by changes in operating conditions made during this period. A complete approach to equilibrium was prevented because there was a net loss of solvent from the system. Analytical efforts during the operating period, improved the accuracy and significance of material balance data. Elemental balances were calculated for several test runs and reflect favorably on the quality of the data and calculations.

6.12.4
SRC TECHNICAL REPORT NO. 6
ANALYSIS OF OPERATIONS
RUNS 9 THROUGH 18
27 AUGUST 1974 TO 20 JANUARY 1975
A. G. DRAEGER, et.al.
SOLVENT REFINED COAL PILOT PLANT
WILSONVILLE, ALABAMA

Abstract: Runs 9 through 18 cover a 95-day period for the SRC Pilot Plant between 9 September and 23 December, and include 75 days of sustained operation from 9 October to 23 December. During the latter period, the on-stream (on-coal) factor was over 95% with the Filter in service 70% of this time. The operability/reliability of all major processing areas in the plant have been fully demonstrated with the exception of the ash drying. Initial operation concluded the testing of W. Kentucky No. 14 coal @ 800°F, 1700 psig reaction conditions, and the pilot plant unit changed over to Illinois No. 6 coal on 16 October.

A total of 10 test runs were evaluated during the period, all but the first on Illinois No. 6 coal. Reaction conditions were varied considerably. Sufficient data were available to correlate the coal conversions as a function of the hydrogen consumption, to determine the effect of reaction conditions upon hydrogen consumption, and to determine the effect of hydrogen consumption upon organic yields.

Sufficient data were available to correlate B102 Slurry Preheater heat transfer performance. B102 inside film coefficients were found to agree well with standard correlations. The coal concentration is a significant factor in heat transfer.

The pilot plant was shutdown for inspection/repairs during January. The R101 Dissolver was found to be free of deposits. There was very little (approximately 10 mils) wall reduction around the B102/HP piping system after 3700 hr. of operation with coal. Some severe erosion occurred in filter feed service in the control valves, downstream elbows, and slurry pumps. Slurry pumps have been spray metallized with an alloy containing nickel, chromium, and boron to improve erosion resistance.

Severe erosion/corrosion was observed on the Type 410 SS Flexitrays in T102 Vacuum Column below the recovered solvent trapout tray. Reasons for this unexpected attack have not been defined. B103 Vacuum Preheater showed no reduction in wall thickness.

6.12.5
SRC TECHNICAL REPORT NO. 7
ANALYSIS OF OPERATIONS
RUNS 19 THROUGH 40
20 JANUARY TO 8 AUGUST 1975
H. E. Lewis, et.al.
SOLVENT REFINED COAL PILOT PLANT
WILSONVILLE, ALABAMA

Abstract: Runs 19 through 40 cover a 102-day period of operation for the SRC Pilot Plant, from 20 January to 18 April (Runs 19-27) on Illinois 6 coal from the Burning Star Mine, and from 19 May to 8 August (Runs 28-40) on Pittsburgh Seam coal from the Loveridge Mine. During the Illinois 6 operating period, the Filter was not operated as an integral part of the process, but rather in a test mode to optimize performance. This also allowed separate reaction studies to be performed over a wide range of conditions to determine limits of operability. Pressures were varied from 1000 to 2400 psig, temperatures from 780 to 840°F, concentrations from 25 to 40%, and coal rates from 13 to 50 lb/hr-ft³ (including previous Illinois 6 test runs). Typical ranges of reaction performance were as follows:

Coal Solution, %	82-94
H ₂ Consumption, %	1.5-3.5
Product Yield, %	50-75
Sulfur, %	0.7-1.1

Operation at 1000 psig resulted in low conversions and less stable reaction.

Kinetic models were developed for coal solution and desulfurization. Tests were also conducted to determine vapor/liquid equilibrium constants (k values) for major SRC process components (hydrogen, solvent fractions). These are used to calculate heat of reaction and hydrogen partial pressure in the Dissolver.

Stable reaction performance on Pittsburgh coal at 33% concentration was demonstrated over a 30 day period. Organic desulfurization of Pittsburgh coal proved more difficult than for either Illinois 6 or W Kentucky 9/14. Increase in temperature from 855 to 870°F at 33% concentration decreased the product sulfur level from 0.9 to 0.8%.

Substantial improvement in Filter performance has been achieved during the period.

6.12.6
SRC TECHNICAL REPORT NO. 8
ANALYSIS OF OPERATIONS
RUNS 41 THROUGH 61
8 AUGUST TO 31 DECEMBER 1975
H. E. Lewis, et.al
SOLVENT REFINED COAL PILOT PLANT
WILSONVILLE, ALABAMA

Abstract: Illinois No. 6 bituminous coal from Monterey No. 1 Mine of Monterey Coal Company and Wyoming subbituminous coal from Belle Ayr Mine of Amax Coal Company were processed. The Monterey coal contained 3% organic sulfur as compared to 2% for previous Illinois No. 6 coal from Burning Star Mine. The Wyoming coal processed contained 21-6% moisture with 0.5% sulfur on a MF basis. The filter system was in operation to produce low-ash product during operating periods for each coal. Filtration rates varied from 10-50 gph/ft².

The filter cake is vacuum-dried on the filter leaves.

The results of pilot plant operations to date show that longer residence times, higher temperatures, and higher pressures, 1. decrease the yield of SRC product, 2. decrease the sulfur content of SRC product, 3. increase the production of liquids and gases, and 4. increase the consumption of hydrogen.

Two new pieces of equipment were installed and operated during normal test runs. The first, a Dorr-Oliver, Merco PC-9, disc-nozzle bowl centrifuge, was tested and a scale-up correlation developed.

The second new unit, a Rexnord Solidifier (K125) with indirect cooling, was installed as an alternate to the direct water-quench solidifier. The indirect solidifier produces moisture-free SRC having a bulk density of 45 to 50 lb/ft³ compared to 35 lb/ft³ for the wet product from the direct-quench solidifier.

6.12.7

SOLVENT REFINING OF COAL: A PROGRESS REPORT

Huffman, E.L.
Southern Services, Inc.
Birmingham, Alabama
Oklahoma State University 1975
Frontiers of Power Technology Conference
Stillwater, Oklahoma

Abstract: In order for power plants to burn much Eastern U.S. high-sulfur high-ash coal in an environmentally acceptable way, either the coal must be cleaned prior to combustion or the flue gas must be cleaned after combustion. The solvent refining process is a most promising option for making clean fuel from coal. Results of a pilot plant project by the Edison Electric Institute and the Southern Co. are reported. Solvent Refined Coal has a heating value of about 16,000 BTU per pound, an ash content of less than 0.15 percent, and a sulfur content of less than 0.9 percent, the properties are generally independent of the type of coal fed to the process. The product can be used directly as a hot viscous liquid or it can be cooled and solidified for easier handling and storage. Although reliable costs cannot yet be made for commercial production, it appears that the SRC process will be competitive with flue gas processing and less expensive than some competing processes for converting raw coal into a clean fuel because it requires less hydrogen, less capital and operating expense (due to less severe conditions), and requires no catalyst. With such clean fuel, a number of other economies related to power plant construction are possible and are listed. Pilot plant results of varying operating pressure, temperature, feed rate, mineral separation processes, etc. are reported. Some problems occurred with pumps and valves.

6.12.8

STATUS OF WILSONVILLE SOLVENT REFINED COAL PILOT PLANT. EPRI 1234, INTERIM REPORT, MAY 1975

Southern Services, Inc. Birmingham, Alabama
Prepared for Electric Power Research Institute, 3412 Hillview Avenue
Palo Alto, California

Abstract: This report is a Historical and Technical Summary of work at the solvent refined coal pilot plant at Wilsonville, Alabama from March 16, 1972 to December 31, 1974. The Southern Company system and the Edison Electric Institute jointly began this pilot plant project to study the key steps in the solvent refining process for making a low-sulfur and low-ash solid fuel from coal in March, 1972. Southern Services, Inc. (SSI) represents The Southern Company system and provides management for the project.

(cont'd)

In April, 1973, the Electric Power Research Institute (EPRI) assumed the functions for the utility industry project supervision, which were formerly carried out by Edison Electric Institute. The EPRI project number for this pilot plant program is RP1234.

The six-ton-per-day pilot plant was designed, built, and is being operated by Catalytic, Inc. The pilot plant was built and preoperational testing was completed in 1973. Operation with coal began in January, 1974.

The pilot plant facilities and operations are described in this summary report. Appropriate engineering flow diagrams and descriptions of major items of equipment are included to aid in understanding the pilot plant operations. The results of pilot plant operations are discussed and summaries of the data and results are presented.

6.12.9.

SOLVENT REFINED COAL (SRC) PROCESS OPERATION OF SOLVENT
REFINED COAL PILOT PLANT AT WILSONVILLE, ALABAMA

Quarterly Technical Progress Report, January-March 1976

Lewis, H.E.

Catalytic, Inc., Wilsonville, Alabama

5 Refs

Contract E(49-18)-2270/EPRI-RP-1234-1-2

June 1976

Abstract: During the period 1 January to 31 March 1976 the plant operated on Kentucky 9 and 14 coal. The space rate of the dissolver was varied from 25 to 50 lb/hr-ft/sup 3 using both the full dissolver volume and one-half the dissolver volume. A higher degree of reaction was evident with the one-half volume dissolver arrangement than with identical conditions using the full dissolver. The pressure leaf filter was operated with ten rather than the normal twenty screens. The results for the ten screens filter operation were not conclusive owing to mechanical problems in the filter.

NTIS FE-2270-1

6.12.10

SOLVENT REFINED COAL (SRC) PROCESS. OPERATION OF SOLVENT
REFINED COAL PILOT PLANT AT WILSONVILLE, ALABAMA

Quarterly Technical Progress Report, April-June 1976

Lewis, H.E.

Catalytic, Inc., Wilsonville, Alabama

Contract E(49-18)-2270/EPRI-RP-1234-1-2

August 1976

Abstract: The operating conditions and results of the six-ton-per-day solvent refined coal (SRC) pilot plant at Wilsonville, Alabama for the second quarter of 1976 are presented. Kentucky 9 and 14 coal was processed during the period, with an on-stream factor of 90 percent. The entire plant performed well. Conditions were chosen to be similar to those of the 50-ton-per-day SRC pilot plant at Fort Lewis, Washington. The same level of reaction performance, as reported by Fort Lewis, was achieved. To achieve this level, it was necessary to use a similar reaction configuration and solvent boiling range. The pressure-leaf filter was on-stream for most of the period. SRC contained 0.1 percent ash, 0.7 to 0.9 percent sulfur. Evaluation of disc and solid bowl centrifuges, and a hydroclone, was also carried out.

NTIS FE-2270-3

6.12.11

SOLVENT REFINED COAL (SRC) PROCESS. OPERATION OF SOLVENT
REFINED COAL PILOT PLANT AT WILSONVILLE, ALABAMA

Quarterly Technical Progress Report for the period July-Sept. 1976

Lewis, H.E., et al

February 1977

Abstract: This document presents the operating conditions and results of the six-ton-per-day Solvent Refined Coal (SRC) pilot plant at Wilsonville, Alabama for the period of July through September 1976.

The first half of the reporting period was used for planned maintenance and modifications, and to condition process solvent. During the remainder of the period, Illinois 6 coal from the Monterey mine was processed with an on-stream factor of 82%. Stable operation was achieved at 38.5% coal slurry concentration, using a higher boiling process solvent, similar to that used to achieve a high performance level with Kentucky coal. The pressure leaf filter was on-stream for most of the period. A lower boiling solvent fraction was used to wash the filter cake. Improvements in the filter cycle have significantly reduced the solvent throughput to the vacuum distillation system. Preliminary testing of less expensive, asbestos-free, precoat materials was completed. The process solvent inventory declined during the operating period. However, improvements to the operation of the distillation systems have reduced the loss of process solvent substantially toward the end of the period.

Typical SRC contained 0.1 to 0.3% ash, 0.8 to 1.0% sulfur.

6.12.12

SOLVENT REFINED COAL (SRC) PROCESS. OPERATION OF SOLVENT
REFINED COAL PILOT PLANT AT WILSONVILLE, ALABAMA

Annual Technical Progress Report for the period January-December 1976
Lewis, H.E., Weber, W.H., Usnick, G.B., Hollenack, W.R., Hooks, H. W.
June 1977

Abstract: This report presents operating conditions and results for the six-ton-per-day Solvent Refined Coal (SRC) pilot plant at Wilsonville, Alabama, for the fourth quarter of 1976. It also summarizes conditions and results for the entire year.

The first objective was correlation of the results from Wilsonville with the 50-ton-per-day Ft. Lewis pilot plant operation. This correlation was established processing Kentucky 9 and 14 coal during the first half of 1976. A second objective was to determine the effect of process variables on yield and quality when processing other coals. This was completed for Monterey (Ill. 6) and was continuing into 1977 for Amax Belle Ayr coal.

The effects on the operation of varying the boiling range of the process solvent and the dissolver volume are reported. Also reported are the effects of operating variables on the overall plant solvent inventory balance.

Filtration results show that the filter cake from Amax Belle Ayr coal has a lower resistance, but is more compressible, than the filter cake from either the Kentucky 9 and 14 or the Monterey (Ill. 6) coals. Work with precoat materials, that do not contain asbestos, is described. Other improvements to the filtration system are discussed.

Results from testing of alternate methods for mineral residue separation, such as centrifuges, hydroclones, are described. Background information is reported for installing a system for preliminary evaluation of an antisolvent method for improvement of the mineral residue separation systems.

SRC containing less than 0.16% ash, 0.96% sulfur was produced from each coal processed during the year.

An SRC solidifier, which uses indirect cooling, was developed and the capacity of the machine has been defined. Several alternate methods of solidification were also investigated.

6.13 · REPORTS ON FORT LEWIS PILOT PLANT ·

The operation of the Fort Lewis Pilot Plant has a major impact on the development of SRC technologies. All the reports, monthly, quarterly and annual, are listed. Also listed are papers summarizing the activities at Fort Lewis:

6.13.1

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL. VOLUME III, PART 1. DESIGN OF PILOT PLANT

Pittsburgh and Midway Coal Mining Co., Kansas City, Mo.

Interim Report Jul 67-Jan 71

Jan 71 163p

Contract: DI-14-01-0001-496

Monitor: OCR-53-INT-2

See also PB-234 038.

Abstract: The research project was to design, construct, and operate a pilot plant for demonstration and further development of a process for producing low-ash, low-sulfur fuel from coal. The design includes detailed engineering flow diagrams and specifications for construction and equipment. This report describes the details of the design of all sections of the plant, including utilities and service facilities. In addition, some of the anticipated mechanical and process problems, together with proposed solutions as represented by the actual design, are described. Portions of this document are not fully legible.

NTIS PB-234-039/6

6.13.2

PROPOSED PILOT PLANT, FORT LEWIS, WASHINGTON FOR DESULFURIZATION OF COAL BY SOLVENT REFINING

Apr 30 1971

NTIS PB-1938 61-D

6.13.3

SOLVENT REFINED COAL PROJECT. PROGRESS REPORTS, APRIL -- JUNE 1974

Pittsburgh and Midway Coal Mining Co., Merriam, Kansas

1974 126p

Monitor: 18

Abstract: Activities of the Pittsburg and Midway Coal Mining Co. (P and M) on the Solvent Refined Coal (SRC) Project during the period April 1, 1974, through June 30, 1974, are described. These activities include: construction and operation of the SRC Pilot Plant at Ft. Lewis, Washington; laboratory research performed by P and M at Merriam, Kansas, to support the pilot plant operations; supporting research done by others under subcontract to P and M to study certain features of the SRC Process. The detailed activities are given in the body of the report following an introduction describing the background history of the project.

NTIS FE-496-T-3

6.13.4

DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL. VOLUME III, PILOT PLANT DEVELOPMENT WORK. PART 2. CONSTRUCTION OF PILOT PLANT. PERIOD COVERED, JUNE 1972--JUNE 1974

Pittsburgh and Midway Coal Mining Co., Kansas City, Mo.

May 75 163p

Rept No: OCR-53-INT-9

Contract: E(49-18)-496

Monitor: 18

Abstract: A summary is provided of the construction of a 50 ton per day pilot plant on a site located at Fort Lewis, a low sulfur, ashless fuel by solvent refining coal. The as-built configuration of the pilot plant is emphasized, and a complete process description is included. Process and design modifications which were made since the original design report was issued are discussed in detail. The report also includes an equipment list, equipment and piping specifications, as-built drawings, and photographs of the plant-site at various stages of construction.

NTIS FE-496-T2

6.13.5

SOLVENT-REFINED COAL (SRC) PROCESS

Energy Research and Development Administration, Washington, D.C. (USA),
Office of Fossil Energy

Pittsburgh and Midway Coal Mining Co., Merriam, Kansas

1975

Coal Liquefaction, quarterly report, January--March 1975

ERDA--114-75 1

Abstract: During the first quarter of 1975, operation of the SRC Pilot Plant continued. Problems experienced with the mineral residue dryer were solved, and the filtration area of the plant was revised to improve the operability of the filters. A material balance run was conducted to determine overall process yields/a positive net yield of solvent was obtained and the recovery of all elements from the feed coal was good. Laboratory research by P and M included experiments using the two-dissolver/reactor configuration to study filtration rates, solvent recycling, decreased slurry residence time, increased concentration of coal in the slurry, and temperature variations, Oklahoma State University conducted experiments to test the capability of various catalysts to remove sulfur and nitrogen from coal liquids, results indicated that Nalco 474 catalyst, tested previously, was preferred. At Washington State University, research on gasification of coal mineral residue from the pilot plant showed that no recovery of elemental iron from the residue was obtained under the conditions investigated.

6.13.6
SOLVENT-REFINED COAL (SRC) PROCESS

White, P. C.
Energy Research and Development Administration, Washington, D. C. (USA)
Office of Fossil Energy
1975
Coal Liquefaction, Quarterly Report, April--June 1975
ERDA--76-33-2

Abstract: Operation of the SRC Pilot Plant continued. The mineral separation area, however, has not yet been placed in operation. During April 11, filter runs were conducted, cake blinding, penetration adversely affected the filtration rate. During a material balance check it was determined that elemental balance error ranged from 0 to 23 percent, the filtration area, the solvent recovery area, and the hot solvent-coal blending unit were repaired and modified during April. The Plant operated only 6 days during May because of mechanical and operational problems. During June, the Plant operated for 25 days, three material balance runs were conducted and reasonable elemental balance closure was obtained for all runs. Laboratory research by P and M explored ways to improve slurry recycle. A new reactor unit is being designed and constructed that will reach the approximate efficiencies of the pilot plant reactor dissolver configuration. The new reactor design will permit studies of the effect of varying slurry residence time in the dissolver. Two experimental runs were conducted during June. Using various commercial catalysts, Oklahoma State University conducted several tests to determine the rate of decay of hydrogenation catalyst activity over a 200-hr operating period. Washington State University continued to conduct experimental work on coal mineral residue from the pilot plant.

6.13.7
PROGRESS REPORT OF PILOT PLANT WORK ON THE SOLVENT REFINED COAL PROCESS

Chenoweth, G. E.
University of Pittsburgh, 1975
Second Annual Symposium on Coal Gasification, Liquefaction, and Utilization: Best Prospects for Commercialization

6.13.8
SOLVENT REFINED COAL (SRC) PROCESS. QUARTERLY REPORT

July--September 1975
Pittsburgh and Midway Coal Mining Co., Kansas City, Mo.
Oct 75 50p
Contract: E(49-18)-496
Monitor: 18

Abstract: Progress is summarized for the Solvent Coal (SRC) project by the Pittsburgh and Midway Coal Mining Co. Activities include the operation of the Solvent Refined Coal Pilot Plant at Ft. Lewis, Washington and process development performed at the Merriam, Kansas Laboratory.

NTIS FE-496-109

6.13.9
SOLVENT REFINED COAL (SRC) PROCESS. ANNUAL REPORT, 1975

Pittsburg and Midway Coal Mining Co., Kansas City, Mo.
Energy Research and Development Administration.
Mar 76 65p
Contract: E(49-18)-496
Monitor: 18

Abstract: The Ft. Lewis SRC Process Pilot Plant completed start up operations after a total of 16 material balance runs. Five material balance runs were made in the new SRC II or slurry recycle mode for the production of liquid rather than solid SRC. In September the Pilot Plant began the Combustion Test-Production Run to produce 3000 tons of low-sulfur, low-ash SRC for testing in a commercial electrical generating facility. All units within the plant with the exception of the prilling tower have been tested and successfully operated. This was not, however, possible without making extensive modifications, particularly in the Mineral Separation (Filtration) Area and Fractionation Area. Development efforts at the SRC Laboratory in Merriam, Kansas, continued to be directed toward the SRC II process. Slurry recycle runs were made at various operating conditions and using different coals. Special studies designed for Ft. Lewis operations were also made. SRC I runs were conducted in the lab at conditions used in the SRC Pilot Plants at both Ft. Lewis and Wilsonville. Supporting research at Washington State University on the recovery of iron from the SRC mineral residue via gasification continued through 1975, but at a slower pace than in past years. The Nuclear Radiation Center at Washington State, completed all preliminary work for trace element determination by neutron activation analysis.

NTIS FE-496-115

6.13.10

COAL PROCESSING: OPERATION OF THE SRC PILOT PLANT

Pastor, G. R., Keetley, D. J., Naylor, J. D.
Pittsburgh and Midway Coal Mining Co., Dupont, Wa.
Chemical Engineering Prog. 72 8 Aug 1976
67-68

Abstract: A Solvent Refined Coal (SRC) Pilot Plant with a design capacity of 50 ton day has been operating successfully since 1974 at North Ft. Lewis, Washington, providing a good deal of useful data on the operation of this process. Since startu the plant has been operated with three primary objectives: (1) to demonstrate and maintain mechanical integrity and operability of all process units, (2) to gather materials, balance and process operating data, and (3) to produce sufficient quantities of products for evaluation and testing. The entire plant has been operated successfully and reliably over a wide range of conditions and at coal rates from 50 to 130 percent of design. Almost all process and mechanical problems encountered to date have been those associated with slurry handling and transport relative to the unit operations of fluid flow, momentum transfer, solids separation, and heat transfer in process streams containing solids. Generally, it appears from the foregoing experience that the SRC Pilot Plant can attain an on-stream operating factor between 80 and 90 percent. As a result of the process variables studies, conditions have been found which allow for production of recycle solvent in excess of that necessary for process operation. Also it has been shown that SRC, the principal product of the process, can be produced in a form low in sulfur and ash.

6.13.11

SOLVENT-REFINED COAL (SRC) PROCESS

Energy Research and Development Administration, Washington, D. C. (USA)
Office of Fossil Energy 1976
Coal Liquefaction, Quarterly Report, July--September 1976
ERDA--76-33-3

Abstract: The SRC Pilot Plant operated for a total of 77 days during the quarter. Three material balance runs were made using distillate solvent, and five runs were made in the slurry recycle mode. Operation was then switched back to the distillate solvent mode, and 70 tons of product for combustion testing were produced before the plant had to be shut down for maintenance overhaul. Process variables were changed in order to find optimum operating conditions. But effects of the variables have not yet been clearly defined. Minor problems continued to plague the overall operation of the Pilot Plant, and work to find satisfactory filters and dryers continued throughout the period. Lab-
(cont'd)

oratory research activities included several runs in the small reactor to determine optimum conditions for operation in the slurry recycle mode. Steady-state operation was difficult to achieve because of mechanical problems, and only a few runs could be considered completely satisfactory. Results of other studies indicated that a decrease in the residence time of coal in the reactor and in the temperature of the reactor lowered the yield of product filtrate and slightly lowered hydrogen consumption.

6.13.12

ANALYSIS OF SRC PILOT PLANT DATA - COMPARISON OF SRC PILOT PLANT DATA
COMPARISON OF WILSONVILLE AND FT. LEWIS PILOT PLANTS. TASK 012. FINAL
REPORT.

TRW, Energy Systems Planning Division, McLean, Virginia 22101
Prepared for the United States Energy Research and Development Administration
Under Contract No. E(49-18)-2213.
No. 2213-12-01

ABSTRACT: Correlation of data from the Ft. Lewis, Washington (50 ton/day) and Wilsonville, Alabama (6 ton/day) Solvent Refined Coal (SRC) pilot plants has shown that a good match exists between yields of SRC and most other products for runs with corresponding temperature, residence time and solvent boiling range. A noticeable difference exists in hydrogen consumption which may be explained by experimental error or by differences in dissolver height/diameter ratio (24/1 for Wilsonville vs 15/1 for Ft. Lewis) and residence time-temperature severity in the preheater. Therefore, for scale-up with coal similar to Western Kentucky 9 and 14, data from either pilot plant could be used.

Computer time-sharing programs for calculating the time-temperature reaction severity in the dissolver and preheater-transfer line sections of both pilot plants are presented. Equations for predicting product yields, hydrogen consumption and SRC sulfur content in terms of these severity parameters have been developed which show good statistical significance and fit to the data.

These results may not apply to other feed sources, since great differences exist in the reactivity and ash and sulfur content of different coals. All of the runs in this study have been at high conversion levels, between 91 and 96%, while the lower conversions associated with less reactive coals may increase the importance of different variables. For slow reacting coals, such as Wyoming sub-bituminous, further parallel runs in the two pilot plants may be justified.

6.13.13

SOLVENT REFINED COAL (SRC) PROCESS. DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS, LOW-SULFUR FUEL FROM COAL. VOLUME III - Pilot Plant Development Work. Part 3 - Startup and Operation of the SRC Pilot Plant

Research and Development Report No. 53 - Interim Report No. 22

Period of June 1974 - April 1977

Pittsburg & Midway Coal Mining Co., Merriam, Kansas

May 1977

Prepared for the United States Energy Research and Development Administration

Abstract: This report covers the activity at the Fort Lewis SRC Pilot Plant : over about a three year period from the time the various sections of the plant were accepted from the construction contractor in early 1974 until mid-April, 1977. Several different phases of operation conducted during this period are discussed. The performance and problems encountered during this entire period of operation are reported in detail. The report covers such topics as: Plant Commissioning; Preliminary Integrated Plant Operation; SRC-I Material Balance Runs; SRC-II (Slurry Recycle) Operation; SRC-I Production Run; Filter Studies and SRC- II Modifications. During the period covered by this report, major progress was made in the further development of the SRC process on a pilot plant scale. Most of the advancements can be directly utilized in the design of future larger plants and thus major steps have been made toward the commercialization of both the SRC-I and the SRC-II processes.

NTIS FE-496-T13

6.14 BIBLIOGRAPHIES

Listed are extensive bibliographies with abstracts published by NTIS on:

Mineral Fiber Production from Coal Minerals

Chemical Characterization and Refining of SRC to Liquid Fuels

Coal Gasification and Liquefaction Technology (in 3 volumes)

6.14.1
COAL PROCESSING
GASIFICATION, LIQUEFACTION DESULFURIZATION
A BIBLIOGRAPHY 1930-1974

Atomic Energy Commission
October 1974

Abstract: This bibliography includes publications on coal processing such as: Carbonization, Desulfurization and Purification, Hydrogenation, Gasification, Liquefaction, Pyrolysis and Cracking and Solvent Extraction. Also included are papers on By-Products, Properties and Waste Management. A Personal Author Index, Subject Index, and Report Number Index are also given.

NTIS-TID-3349

6.14.2
DEVELOPMENT OF A PROCESS FOR PRODUCING AN ASHLESS LOW SULFUR FUEL FROM COAL.
VOLUME IV, PRODUCT STUDIES. PART 2. ANNOTATED BIBLIOGRAPHY ON MINER FIBER
PRODUCTION FROM COAL MINERALS

Pittsburg and Midway Coal Mining Co., Kansas City, Mo. Office of Coal
Research, Washington, D. C. Washington State University, Pullman College
of Engineering Research Div.
Interim Report No. 10

Nov 74 71p

Contract: DI-14-01-0001-496

Monitor: OCR-53-INT-10

See also PB-234 039, and PB-237 764. Prepared in cooperation with Washington
State Univ., Pullman. College of Engineering Research Div.

Abstract: This report summarizes the literature search performed in support
of research on mineral fiber production from the residual solids of the
Solvent Refined Coal (SRC) Process.

NTIS PB-237 763/8ST

6.14.3
CHEMICAL CHARACTERIZATION, HANDLING AND REFINING OF SRC TO LIQUID FUELS. A
BIBLIOGRAPHY OF ENGLISH REFERENCES FROM 1957 TO 1975. TASK 1 REPORT

Air Products and Chemicals, Inc., Allentown, PA. Corporate Research Dept.

*Energy Research and Development Administration

Alexander, W., Collura, M.A., Hart, W.A., Wetherington, J.B.

Jan 76 69p

Contract: E(49-18)-2003

Monitor: 18

Abstract: A Bibliography of English language references on the liquefaction
of coal, hydrotreating, hydrocracking, and analysis and properties of solvent-
refined coal and similar materials from 1957 to 1975 is presented.

NTIS ERDA-76-68

6.14.4

DESULFURIZATION OF COAL AND PETROLEUM (A BIBLIOGRAPHY WITH ABSTRACTS)

National Technical Information Service, Springfield, Va.

Report for 1964-May 76

Werner, Kirk G., Cavagnaro, Diane M.

May 76 200p

Monitor: 18

Supersedes NTIS/PS-75/381 and COM-74-10935

Abstract: The bibliography is divided into two sections covering all aspects of coal and petroleum fuel desulfurization. Coal gasification, liquefaction, and solvent refining processes which specifically accomplish desulfurization are included. Flue gas desulfurization and other post-combustion sulfur control processes are not covered. Coal gasification and liquefaction studies are only included if sulfur removal is stressed. (This updated bibliography contains 195 abstracts, 68 of which are new entries to the previous edition.)

NTIS PS-76/0399/6ST

6.14.5

COAL GASIFICATION AND LIQUEFACTION TECHNOLOGY: VOLUME 1. 1964-1973 (A BIBLIOGRAPHY WITH ABSTRACTS)

National Technical Information Service, Springfield, Va.

Report for 1964-73

Werner, Kirk G., Cavagnaro, Diane

May 76 146p

Monitor: 18

Supersedes NTIS/PS-75/385.

Abstract: The bibliography covers the techniques and processes of the conversion of coal to gaseous and liquid chemicals as well as coal derived fuels. References to solvent refined coal are included but in situ combustion (underground gasification of coal deposits) are not. Coal desulfurization, cleaning or preparation which does not involve conversion to gas or liquid fuel are not covered. Also excluded are environmental studies. Reports announced by NTIS after 1973 have been included if the research was done between 1964-1973. (This updated bibliography contains 141 abstracts, 20 of which are new entries to the previous edition.) See also NTIS/PS-76/0222, Pollution and Environmental Aspects of Fuel Conversion.

NTIS/PS-73/0390-5ST

6.14.6

COAL GASIFICATION AND LIQUEFACTION TECHNOLOGY. VOLUME 2. 1974-May 1976
(A BIBLIOGRAPHY WITH ABSTRACTS)

National Technical Information Service, Springfield, Va.

Report for 1974-May 76

Cavagnaro, Diane M.

May 77 205p

Monitor: 18

Abstract: Cited are Federally-sponsored reports on the conversion of coal to gaseous and liquid chemicals. This includes solvent refined coal liquids and coal derived fuels. It does not cover any coal desulfurization where environmental effects are involved or in situ combustion (underground gasification of coal deposits). The cleaning or preparation of coal has been excluded unless it is mentioned as part of a coal conversion process. (This updated bibliography contains 205 abstracts, none of which are new entries to the previous edition.) See also NTIS/PS-76/0390, Coal Gasification and Liquefaction Technology. Vol. 1. 1964-1973 and NTIS/PS-77/0305, Coal Gasification and Liquefaction Technology, Vol. 3. June 1976-April 1977.

NTIS/PS-77/0304/4ST

6.14.7

COAL GASIFICATION AND LIQUEFACTION TECHNOLOGY. VOLUME 3. JUNE 1976-APRIL 1977 (A BIBLIOGRAPHY WITH ABSTRACTS)

National Technical Information Service, Springfield, Va.

Report for June 76-April 77

Cavagnaro, Diane M.

May 77 125p

Monitor: 18

Supersedes NTIS/PS-76/0391, NTIS/PS-75/386, and COM-74-10967

Abstract: Techniques and processes of the conversion of coal to gaseous and liquid chemicals are cited in this bibliography. It also includes solvent refined coal liquids and coal derived fuels. Coal desulfurization, cleaning or preparation which does not involve conversion to gas or liquid fuels, or in situ combustion (underground gasification of coal deposits) are not covered. (This updated bibliography contains 120 abstracts, all of which are new entries to the previous edition.) See also NTIS/PS-76/0390. Coal Gasification and Liquefaction Technology. Vol. 1. 1964-1973 and NTIS/PS-77/0304 Coal Gasification and Liquefaction Technology. Vol. 2 1974-May 1976.

NTIS/PS-77/0305/1ST

Distribution for ANL/ECT-3, Appendix B

Internal:

E. M. Bohn (5)	R. G. Matlock
W. L. Buck	N. M. O'Fallon
L. Burris	E. G. Pewitt
E. J. Croke	G. N. Reddy (5)
W. A. Ellingson	G. S. Rosenberg
P. S. Farber	N. F. Sather
J. Fischer	W. K. Sinclair
B. L. Graves	A. Tevebaugh
H. S. Huang	S. Vogler
R. O. Ivins	R. W. Weeks
A. A. Jonke	K. E. Wilzbach (56)
A. B. Krisciunas	S. H. Wong
J. A. Lecky	R. S. Zeno
G. Leppert	ANL Contract Copy
C. D. Livengood (5)	ANL Libraries (5)
K. Macal	TIS Files (6)

External:

DOE-TIC (27)

Manager, Chicago Operations Office

Chief, Office of Patent Counsel, CH

President, Argonne Universities Association

Energy and Environmental Systems Division Review Committee:

E. E. Angino, U. Kansas
T. G. Frangos, Madison, Wis.
J. H. Gibbons, U. Tennessee
R. E. Gordon, U. Notre Dame
W. Hynan, National Coal Association
D. E. Kash, U.S. Geological Survey, Reston, VA
D. M. McAllister, U. California, Los Angeles
L. R. Pomeroy, U. Georgia
G. A. Rohlich, U. Texas at Austin
R. A. Schmidt, Electric Power Research Inst.
R. Balzhiser, Electric Power Research Inst.
L. L. Brothers, Committee on Science & Technology, U.S. House of Representatives
M. J. Deutch, Washington, DC
E. R. Frederick, Air Pollution Control Association, Pittsburgh
T. J. Chu, Tennessee Valley Authority
L. C. Goidell, U.S. Department of Energy, Aiken, SC
M. Gottlieb, U.S. Department of Energy (25)
A. S. Gupta, Air Products and Chemicals, Inc. (10)
W. B. Harrison, Southern Company Services, Inc. (3)
G. Higginson, Catalytic, Inc.
H. Mittelhauser, Mittelhauser Corporation, Lisle, IL
D. B. Peterson, Energy Resources Conservation and Development Commission,
Sacramento, CA

J. A. Pryor, Air Products and Chemicals Inc.
E. S. Rubin, Carnegie-Mellon University
M. Sze, The Lummus Co., Bloomfield, NJ
L. Udani, Catalytic, Inc.
E. E. Varanini III, Energy Resources Conservation and Development Commission,
Sacramento, CA